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PRELIMINARY TRIALS WITH CITRAZON—A SELECTIVE ACARICIDE[1]

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ABSTRACT

Citrazon (Ethyl O-benzoyl 3 chloro-2, 6-dmethoxy benzohydroximate) was compared with two organotin acaricides Plictran and Vendex for mite control on apples and pears. Citrazon controlled the phytophagous European red mite, **Panonychus ulmi** (Koch) as effectively as Plictran and Vendex and all were low in toxicity to the phytoseiid mites, **Typhlodromus occidentalis** Nesbitt and **T. columbiensis** Chant. Unlike Plictran and Vendex, Citrazon was much less toxic to another predatory mite, **Zetzellia mali** Ewing, and to the pear rust mite, **Epitrimerus pyri** (Nal.).

An essential feature of a good acaricide for integrated mite control is that it be selective. The ideal one would be toxic to all harmful mites but innocuous to the beneficial mites. When used at the half-inch green bud stage, mineral oil is very selective as it is toxic to the eggs of the European red mite, *Panonychus ulmi* (Koch), but has little toxicity to the predaceous phytoseiid mites, eg. *Typhlodromus occidentalis* Nesbitt, or to apple rust mite, *Vasates schlechtendali* Nal., (Downing 1967). Rust mites are an important alternate food source for phytosiids as shown by Collyer (1964) and help to make integrated mite control a success. Oil, however is not the ideal acaricide as it can be phytotoxic and cannot be used with safety during the summer season. Propargite and the new organotin acaricides such as Plictran and Vendex are selective as they are toxic to European red mite, McDaniel spider mite, *Tetranychus mcdanieli* McG., and have low toxicity to the predaceous mite *T. occidentalis.* However, these acaricides are toxic to rust mites and to another predaceous mite, *Zetzellia mali* Ewing, and may under certain circumstances do more harm than good. This is a report of laboratory and field trials with a new acaricide, Citrazon.

MATERIALS AND METHODS

Citrazon was introduced by Nippon Soda Co. Ltd., Tokyo, Japan, and is being developed in Canada by Ciba-Geigy Canada Ltd. Its chemical identity is Ethyl 0-benzoyl 3-chloro-2, 6-dimethoxy benzohydroximate. Citrazon, 20% emulsifiable concentrate was compared with the following selective acaricides in laboratory and orchard experiments:

Plictran 50% wettable powder,
tricyclohexyltin hydroxide. Vendex
50% wettable powder, Hexakis (beta,
beta-dimethylphenethyl)-distannoxane.

[1]Contribution No. 415, Research Station, Agriculture Canada, Summerland, B.C.

Laboratory and Greenhouse Experiments

Toxicities of Citrazon and Plictran against the native mite predators, *T. occidentalis, T. columbiensis* Chant and *Z. mali,* were tested in a Potter Spray Tower. Five predators were placed on waxed black paper. This was floated on cotton saturated with water in petri dishes. Dishes were placed in the spray tower and exposed to 2 ml of the spray mixture. Treatments were replicated 6 times. Examination of the predators with a steremicroscope was made 1, 2, and 3 days after treatment and the percentage mortalities obtained were corrected for natural mortality in the check plots according to the method of Abbot (1925).

European red mites were reared on potted Red Delicious apple trees in a greenhouse and these were sprayed on a turntable with a Kellog-American compressed-air paint gun sprayer that produced a fine even spray at a pressure of 15 lb. per square inch (1 kg per sq. cm). Volume of spray was not measured but each tree was thoroughly sprayed to runoff. Treatments were replicated 5 times. Estimates of mite populations were made 3 and 10 days after spraying by taking 5 leaves from each tree and processing them by the method of Henderson and McBurnie (1943) as modified by Morgan *et al.* (1955).

Orchard Experiments

Sprays were applied with a high volume hand gun sprayer operated at 425 p.s.i. (30 kg per sq. cm) and the trees were sprayed until dripping. Orchard trees were either Red or Golden Delicious on semi-dwarf rootstalk or Bartlett pears, all spaced 7½ ft. by 15 ft. (2.28 m x 4.57 m). Plot size was 3 trees with 3 replicates per treatment except for the experiment summarized in Table 3 in which only 2 replicates were available. Estimates of mite populations were made on 25-leaf samples taken from the middle tree of each replicate and processing these as above.

RESULTS AND DISCUSSION

Laboratory and Greenhouse Experiments

Table 1 shows that neither Citrazon 20% E.C. 0.5 pt (284 ml) nor Plictran 50% W. P. 4 oz. per 100 gal. (25 gm per 100 1) were toxic to the 2 predaceous phytoseiid mites, *T. occidentalis* or *T. columbiensis* Chant: that Citrazon was not toxic to the predaceous stigmaeid mite, *Z. mali,* but Plictran was. *T. occidentalis* is the most important of the 3 predators but under certain conditions the other predators may be valuable in regulating the densities of European red mite. *T. columbiensis* is much more cold-hardy than *T. occidentalis* and sometimes after a very cold winter is the only phytoseiid species that is present in commercial orchards. *Z. mali* unlike *T. occidentalis,* can usually survive when prey densities are very low and is sometimes the only predeaceous mite found in some commercial orchards.

TABLE 1. Corrected percentage mortalities of mites in petri dishes 3 days after application of acaricides in a Potter Spray Tower.

Acaricide per 100 gal.	T. occidentalis	T. columbiensis	Z. mali
Citrazon 20% E. C. 0.5 pt.	0	3	0
Plictran 50% W. P. 4 oz.	0	0	78

Citrazon and Plictran were equal in toxicity to the European red mite and *T. occidentalis* on apple trees in greenhouse trials. Both acaricides controlled the phytophagous mite and allowed some survival of the predaceous mite as shown in Table 2.

Orchard Experiments

Vendex and Citrazon showed a low toxicity level when tested against *T. occidentalis* on Red Delicious apple trees. Even 1 pt per 100 gal. concentration (125 ml per 100 litre) of Citrazon, which is twice the concentration of active ingredient of either Vendex or the lower rate of Citrazon, allowed good survival of this predatory species (Table 3). On Golden Delicious trees, Citrazon gave quicker control of European red mite and was almost non toxic to *Z. mali.* Vendex, on the other hand, was slow in controlling the red mite and quite toxic to the predator *Z. mali* as summarized in Table 4.

TABLE 2. Numbers of mites per 25 leaves after application of acaricides to potted apple trees in a greenhouse.

Acaricide per 100 gal.	European red mite		T. occidentalis	
	3 days	10 days	3 days	10 days
Citrazon 20% E. C. 0.5 pt	12	2	6	1
Plictran 50% W. P. 4 oz.	12	10	1	2
Check - no treatment	260	378	11	17

Citrazon was compared with Plictran against the pear rust mite, *Epitrimerus pyri* (Nal.), and as shown in Table 5, Citrazon 20% E.C. at 0.5 pt. or 1 pt. per 100 gal. (62.5 ml or 125 ml per 100 1) did not give adequate control whereas control with Plictran was excellent.

TABLE 3. Numbers of T. occidentalis per 50 leaves before and after application of acaricides to orchard apple trees with a high volume hand gun sprayer, 18 July 1973.

Acaricide per 100 gal.	Before spraying	After spraying		
	July 17	July 24	Aug. 1	Aug. 9
Citrazon 20% E. C. 0.5 pt	90	21	23	24
Citrazon 20% E. C. 1.0 pt	119	11	9	8
Vendex 50% W. P. 4 oz.	99	15	17	10
Check - no treatment	112	29	28	17

TABLE 4. Numbers of mites per 75 leaves before and after application of acaricides to orchard apple trees with a high volume hand gun sprayer, 26 June 1973.

Acaricide per 100 gal.	Before spraying	After spraying			
	June 26	July 3	July 11	Aug. 3	Sept. 5
	European red mite				
Citrazon 20% E. C. 1 pt	608	0	8	60	96
Vendex 50% W. P. 4 oz.	1208	121	192	7	33
Check - no treatment	688	348	3082	58	0
	Zetzellia mali				
Citrazon 20% E. C. 1 pt	10	8	37	113	204
Vendex 50% W. P. 4 oz.	21	3	0	3	32
Check - no treatment	29	44	251	174	62

This low toxicity to eriophyid mites such as the pear rust mite or its close relative, the apple rust mite, may be more of an advantage for integrated control programs on apple because, as stated earlier, rust mites are an excellent alternate food source for predaceous phytoseiid mites. Citrazon appears to have qualities that will make it an excellent acaricide for integrated mite control programs on apple. It seems to be sufficiently toxic to European red mite to reduce an outbreak to subeconomic levels. The low toxicities of Citrazon to the predaceous mites, *T. occidentalis, T. columbiensis* and *Z. mali,* and most likely to the alternate food source for the predators, the apple rust mite are very desirable properties of a selective acaricide and would make Citrazon useful for integrated mite control programs on apple.

TABLE 5. Numbers of pear rust mite per 75 leaves after application of acaricides to Bartlett pears with a high volume hand gun sprayer, 16 July 1974.

Acaricide per 100 gal.	Before spraying	After spraying			
	July 15	July 22	July 26	Aug. 7	Aug. 13
	Pear rust mite				
Citrazon 20% E. C. 0.5 pt	30,500	245	296	417	940
Citrazon 20% E. C. 1.0 pt	19,400	80	170	543	846
Plictran 50% W. P. 4 oz.	30,200	4	8	6	28
Check - no treatment	18,900	3016	2016	1704	2108

References

Abbott, W. S. 1925. A method of computing the effectiveness of an insecticide. J. econ. Ent. 18: 265-267.

Collyer, E. 1964. The effect of an alternative food supply on the relationship between two **Typhlodromus** species and **Panonychus ulmi** (Koch) (Acarina). Entomologia exp. appl. 7: 120-124.

Downing, R. S. 1967. Petroleum oils in orchard mite control. J. Entomol. Soc. Brit. Columbia, 64: 10-13.

Henderson, C. F., and H. Y. McBurnie. 1943. Sampling technique for determining populations of citrus red mite and its predators. U.S. Dep. Agric. Circ. 671.

Morgan. C. V. G., et al. 1955. Methods for estimating orchard mite populations, especially with the mite brushing machine. Can. Ent. 87: 189-200.

CODLING MOTH[1] CONTROL BY STERILE INSECT RELEASE: IMPORTATION OF FRUIT AND FRUIT CONTAINERS AS A SOURCE OF REINFESTATION[2]

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ABSTRACT

A program of codling moth, **Laspeyresia pomonella** (L.), control by the sterility principle is planned for the entire Similkameen Valley of British Columbia. If the program is successful, reinfestation by moth fly-in is unlikely because the Valley is fairly well isolated. Importation of host fruits and fruit containers (bushel boxes) for roadside fruit stands could lead to reinfestation unless the boxes are fumigated. Localized annual releases of sterile moths around fruit stands may also be necessary. Orchard bins, used by commercial packinghouses, are unlikely to be a serious source of codling moth reinfestation.

INTRODUCTION

It has been shown that the codling moth, *Laspeyresia pomonella* (L.), can be controlled effectively by release of sterile moths, but the method is about twice as expensive as chemical control if releases have to be made over the entire area every year (Proverbs 1974). Results of small scale sterility programs, in which treated orchards were exposed to fly-in of inseminated female moths from nearby orchards, have indicated that even under these conditions of reinfestation it is usually unnecessary to apply control measures in the first year following termination of sterile moth release, and that in the second year only one spray is required instead of the normal 3-spray program.

An area-wide sterile moth release program is planned for the Similkameen Valley of British Columbia. Because this Valley is semi-isolated, moth fly-in would be virtually eliminated and the effects of the program should persist for some years. Pockets of reinfestation would likely occur from time to time, but it should be possible to eliminate these incipient infestations by localized release of sterile moths. Consequently, in the long run, area-wide control by the sterility procedure probably would be cheaper than chemical sprays.

The validity of this premise was questioned by fruit growers who pointed out that there is some movement of fruit and fruit containers into the Similkameen Valley from distant fruit-growing areas. Plywood bins used for transporting fruit from orchards to packinghouses are moved annually into the Similkameen to service a few growers who have their fruit packed in the neighboring Okanagan Valley. The imported empty bins may contain spun-up larvae and pupae of the codling moth. A more likely source of reinfestation, however, is from boxes of apples and pears that are brought into the Similkameen for sale at roadside fruit stands. Before the fruit is sold and transferred to the purchaser's container, some mature larvae leave the fruit and spin-up in the boxes where they complete development and emerge as adult moths the following spring. This report examines the importance of fruit and fruit containers imported into the Similkameen Valley as sources of codling moth reinfestation after a theoretically successful program of moth control by the sterility method.

MATERIALS AND METHODS

The numbers of moths likely to emerge from empty fruit containers in spring were determined as follows. In early April, before the start of adult moth emergence, 50 one-bushel (ca. 36 dm^3) wooden boxes, the standard fruit container used by fruit stand operators, were taken at random from each of 5 fruit stands in the Similkameen Valley. The boxes were placed in a mothproof room in which the daily temperature fluctuation was between 21° and 27° C and the light/dark regime was 18/6 hr. A screen-mouthed glass jar containing ca. 100 laboratory-reared diapausing larvae was placed in the room to determine whether environmental conditions were satisfactory for pupation and subsequent adult emergence. A similar jar of larvae was held in the laboratory at ca 27° C and a light/dark regime of 18/6 hr. Because there was some doubt about the health of the diapausing insects, 20 mature nondiapausing larvae and 20 pupae were also placed in the room in separate jars. Control nondiapausing insects were kept in the laboratory. A 40-watt black light trap was installed to capture the wild moths as they completed development and emerged from the boxes.

[1]Lepidoptera: Olethreutidae.

[2]Contribution No. 417, Research Station, Summerland

The efficiency of the trap was determined, prior to the start of the adult emergence, by introducing into the room a known number of laboratory-reared moths that were marked externally with Day Glo® fluorescent powder. Later, when emergence of wild moths from the boxes had commenced, the efficiency of the trap was rechecked with moths marked internally with calco oil red. This marking method was adopted to prevent pigment transfer to wild moths which could lead to misidentification of the wild insects. The experiment was discontinued 2 weeks after the last capture of a wild moth.

The procedure for estimating the numbers of moths likely to emerge from bins was essentially the same as that used for boxes. The experiment was conducted in a large storage room in a packinghouse with 500 so-called standard bins (0.8 m^3) from the Summerland district. The daily temperature fluctuation in the room was between ca. 23° and 29° C and the light/dark regime was 17/7 hr. Three screen-mouthed glass jars, each with ca. 100 diapausing larvae, 3 with 10 nondiapausing larvae and 10 pupae, and 2 with ca. 30 adult moths each, were placed at different locations among the bins. Four black light traps were installed, and trapping efficiency estimated, prior to emergence of wild adults, by release of a known number of marked moths. The numbers of traps were later increased to 8, and trapping efficiency reassessed before emergence of wild adults. The experiment was discontinued 3 weeks after the last capture of a wild moth.

Boxes

The environment in the room used for processing the boxes was satisfactory for codling moth development; adult emergence from the caged nondiapausing insects was 95.0% in the room vs. 92.5% in the laboratory. Emergence from caged diapausing insects was much less than that—an estimated 40% in the room and laboratory. Microscopic examination of dead and moribund larvae indicated that poor emergence with caged diapausing insects was due to a severe infection of granulosis virus.

Use of a single black light trap proved to be an effective way of capturing adult moths in the room. In the first trapping efficiency test 25 marked moths were released and they were all captured within 3 days; in the second test 92 moths were released and 84 were captured. Thus the average trapping efficiency was 93.16%.

Twelve wild (unmarked) moths were captured in the black light trap in the 7-week period in which the 250 boxes were exposed to long photophase at 21-27° C.

With respect to importation of fruit during the growing season, only a very small number of codling moths are likely to be introduced with cherries, plums, apricots, and peaches. The fruit itself would not be a carrier for only very rarely are stone fruits infested with the codling moth in British Columbia. If the boxes were used the previous year for handling apples and pears, virtually all the overwintered larvae that were spun-up in the boxes would have completed development and emerged as adult moths before the commencement of stone fruit imports, usually in early and mid July.

Moths could be introduced with imports of late maturing cultivars of peach if the boxes were used earlier in the year for very early maturing cultivars of apples and pears. However, the numbers of moths introduced in this way probably would be extremely small.

Very early maturing cultivars of apples, which might be imported during the third week of July, could be infested with small numbers of late maturing first generation larvae. However, such imports would not contribute measurably to reinfestation since the volume of these imports is relatively small and by the third week in July many or most of the first generation larvae have already completed development and left the fruit.

Large-volume imports of apples and particularly pears normally start in mid August and it is these imports which could play an important role in reinfestation. Some of the fruit would be infested with second generation larvae and virtually all of those that develop to the fifth instar would enter diapause and be potentially capable of starting a new infestation next spring.

We do not know what percentage of the diapausing larvae spin up in the boxes, but because the number of infested apples and pears per box is very small, it seems reasonable to assume that the vast majority of the larvae would hibernate in or on the boxes for there are many attractive spin-up sites in cracks and corners of the boxes. Future investigations will show whether larvae do leave the boxes and whether artificial oviposition sites are needed to trap these larvae.

Fruit stand operators normally use each box several times yearly, sometimes for imported fruit, other times for locally-grown fruit. Despite this it is still possible to estimate the approximate number of overwintered moths that originate from imported fruit if we know the total number of boxes used in the fruit stand business, and the respective volumes of imported and locally-grown fruit sold through this outlet. We must also assume (and there is no reason to believe otherwise) that the per cent codling moth infestation is about the same for imported and locally-grown fruit.

Fruit stand operators use a total of ca. 17,800 boxes in their business, and we estimate that ca. 20% of apples and pears sold after mid August (i.e, that period in which fruit is

infested with second generation larvae) are imported. On the basis of the experiment conducted with the Similkameen boxes, we would expect 917 moths to emerge in spring from 17,800 boxes. About 20% of these, i.e. 183 moths, would be from imported fruit. Since most of the moths would emerge in a 2-3-week period, they could easily start new infestations once sterile insect release is discontinued. The most practical method of eliminating this source of reinfestation is by fumigation of all boxes with methyl bromide during winter.

Even though only small numbers of nondiapausing insects are likely to come into the Valley in boxes of stone fruits and early maturing cultivars of apples and pears, they could conceivably start new infestations. Traps, baited with the synthetic sex pheromone of the codling moth, should be deployed around all fruit stands to monitor adult moth populations. Results of monitoring would indicate whether yearly localized releases of sterile moths should be made around all fruit stands, at least until fruit stand owners can be convinced that they should discontinue importing apples and pears, and that only codling moth free boxes should be used for importing stone fruits.

Bins

The environment in the room used for processing the bins was satisfactory for completion of codling moth development; adult emergence from caged nondiapausing insects was 93.3%. Emergence from caged diapausing larvae was abnormally low, as in the previous experiment with boxes.

Four black light traps were too few to give maximum moth capture in the large room of the packinghouse. When 49 marked adult moths were released only 42 were captured. Caged adult moths lived for several days indicating that the relatively low trapping efficiency (85.7%) was not due to poor adult survival. There was an appreciable increase in trapping efficiency when the number of traps was increased to 8; 94 of 100 released moths were captured within 4 days.

Five wild (unmarked) moths were captured in the light traps during the 7-week period in which the 500 bins were exposed to long photophase at 23-29° C. On the basis of 94% trapping efficiency, emergence in spring would be 1.06 moths/100 bins.

About 2% of the Similkameen fruit growers use imported bins to ship their fruit to Okanagan Valley packinghouses or to outside markets. Import of so-called half bins (0.4 m^3) for the stone fruit harvest is unlikely to contribute to codling reinfestation. Since Golden Delicious is the only host fruit cultivar shipped in half bins, their re-use for host fruits in any one year is very restricted. Consequently, there is only a very limited opportunity for diapausing larvae to spin-up in the bins. Furthermore, the few overwintered larvae that might have been present would have mostly completed development and emerged as adult moths by the time the bins were imported.

We estimate that ca. 530 standard and 290 half bins are shipped into the Similkameen Valley every year for the apple and pear harvest. Empty bins are sometimes imported in spring before adult emergence from overwintered insects is complete. On the other hand, imports are sometimes delayed so long that some of the bins may have already been used for early-maturing host fruits, and consequently may harbor small numbers of nondiapausing larvae and pupae of the first generation. However, the probability of reinfestation is likely to be very low since only ca 820 bins are involved, and only ca. 8 moths should emerge in spring from these bins on the basis of the experiment conducted with Summerland bins. The chances of reinfestation could be further reduced by importing as many bins as possible in early July, i.e., after adult emergence of overwintered insects, but about one week before harvesting host fruits.

There soon may be another potential source of codling moth reinfestation. The British Columbia tree fruit industry is being reorganized and it is possible that some packinghouses may eventually handle only certain species or cultivars of fruit. This would entail a fairly considerable movement of fruit and bins between fruit-growing areas, with consequent increase in the chances of reinfesting the Similkameen Valley. There is only a slight chance that mature larvae will leave infested fruit after it has been imported because the bins of fruit are put into cold storage immediately on arrival at the packinghouses. It is prior to transport, when harvested fruit is often left in orchards for 1 or more days, that mature larvae are likely to leave the fruit and spin-up in the bins. These will be almost entirely diapausing larvae. Consequently, the contribution of imported bins to reinfestation would be limited almost exclusively to the following spring.

The number of moths that emerge from bins in spring evidently is not large enough to create a serious problem of reinfestation. About 11,500 bins are used in the packinghouse operations in the Similkameen Valley. On the basis of our experiment at Summerland, this number would contribute 122 adult moths to the overwintered codling moth population. However, it seems unlikely that more than one-fourth of the bins, i.e. 30 moths, would originate from outside the Valley. If the standard bins were held at Similkameen Valley packinghouses until early July, it should be possible, by releasing small numbers of sterile moths around the packinghouses, to prevent emerging adults

from starting new infestations. The half bins can be fumigated if they have to be distributed to stone fruit growers before all the overwintered insects have emerged. Of course, no bins should be imported before early July in order to avoid introducing overwintered insects.

In conclusion, it seems that the greatest danger of codling moth reinfesting the Similkameen Valley after discontinuance of sterile moth release would be through importation of boxes of apples and pears for the fruit stand trade. Incipient infestations could be suppressed or avoided by fumigating the empty boxes and by localized release of sterile moths. At this time the numbers of imported bins are so small that they are unlikely to contribute to codling moth reinfestation.

Reference Cited

Proverbs, M.D. 1974. Codling moth control by the sterility principle: estimated cost and some biological observations related to cost. Pages 81-88. In Proc. Panel on The Sterile-Insect Technique and its Field Applications. I.A.E.A., Vienna, Austria.

MITES AND INSECTS COLLECTED FROM VINEYARDS IN THE OKANAGAN AND SIMILKAMEEN VALLEYS, BRITISH COLUMBIA[1]

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ABSTRACT

Five species of mites and 122 species of insects were collected from leaves, stickyboards and beating trays in 14 vineyards in 5 different areas in southern British Columbia between May and October 1972. Two mite species and 5 insect species are potential economic pests in British Columbia but only one insect species, the Virginiacreeper leafhopper, Erythroneura ziczac Walsh requires control measures.

INTRODUCTION

A survey of vineyards in the Okanagan and Similkameen Valleys was made in 1972 to determine the species of insects and mites present, their distribution, parasites and predators.

METHODS

Mites and insects were collected from yellow stickyboards hung in vineyards, from grape leaves examined under a binocular microscope and from beating trays. In each vineyard and for each variety the samples consisted of 10 leaves collected randomly, one beating tray count from each of 10 vines and one yellow stickyboard hung on the top trellis wire. Samples were taken and stickyboards changed at weekly intervals from 30 May to 6 October. Insects were mounted or pinned and sent to taxonomists at the Biosystematics Research Institute, Ottawa, for identification. Mites were identified by us along with R. S. Downing and T. K. Moilliet of the Research Station, Summerland, British Columbia. Varieties of grapes sampled were Foch and Bath at Westbank; Campbell Early, Patricia, Himrod, and Sheridan at Kelowna; Riesling, Bath, Diamond and S-10878 at Oliver; Foch at Cawston; S-9549, Diamond and numerous experimental varieties at Summerland.

[1] Contribution No. 403, Research Station, Summerland, B.C.

Insects and Mites Collected in Vineyards in the Okanagan and Similkameen Valleys, British Columbia, 1972

Species	Nos.	Locality	Collection Method	Month Collected
ACARINA				
Phytoseiidae				
Typhlodromus pyri Scheuten	370	Kelowna	leaves	May-Sept.
Typhlodromus occidentalis (?)	36	Westbank, Summerland Oliver, Cawston	leaves	May-Oct.
Tetranychidae				
Tetranychus urticae Koch	33	Westbank, Summerland	leaves	July-Oct.
Panonychus ulmi (Koch)	250	Kelowna, Westbank, Summerland	leaves	June-Oct.
Tydeidae				
Tydeus sp	954	All areas	leaves	May-Oct.
COLEOPTERA				
Anobiidae				
Coelostethus quadrulus LeC	1	Kelowna	board	July
Anthicidae				
Anthicus sp.	2	Oliver	tray	July-Aug.
Lappus nitidulus LeC.	4	Kelowna, Westbank	tray	July
Buprestidae				
Anthaxia deleta LeC.	1	Kelowna	board	July
Anthaxia sp.	12	Kelowna, Summerland	board	June
Carabidae				
Bembidion mutatum Gemm. & Har.	1	Cawston	board	June
Bradycellus californicus LeC.	1	Cawston	board	June
Lebia guttula LeC.	1	Westbank	tray	June
Lebia viridis Say	1	Kelowna	board	June
Chrysomelidae				
Crioceris duodecimpunctata (L.)	1	Oliver	board	Sept.
Epitrix tuberis Gentner	1	Westbank	board	June
Phyllotreta sp.	2	Cawston, Oliver	tray	June & Aug.
Cleridae				
Phyllobaenus humeralis Say or near	9	Cawston	board	July
Coccinellidae				
**Cycloneda polita* Csy.	1	Vernon	board	Sept.
Hippodamia convergens Guerin	3	Kelowna, Westbank, Cawston	board	June
Hippodamia quinquesignata (Kirby)	6	Kelowna	board	June & Aug.
Microwesia sp.	4	Kelowna, Westbank, Summerland	board, tray	Aug.
Scymnus sp.	1	Cawston	board	June
Stethorus sp.	3	Kelowna, Westbank, Summerland	board, tray	July-Sept.
Curculionidae				
Brachyrhinus sulcatus (F.)	2	Kelowna, Westbank	tray	July & Oct.
Miccotrogus picirostris (F.)	1	Summerland	board	July
Sitona cylindricollis Fahr.	1	Westbank	tray	Oct.
Dermestidae				
Cryptorhopalum sp.	1	Summerland	board	July
Elateridae				
Agriotes ferrugineipennis LeC.	1	Cawston	board	June

*Collected at Vernon, B.C. at single sampling.

Cardiophorus edwardsi Horn	3	Summerland, Cawston	board	June
Dalopius sp.	1	Oliver	board	June
Limonius infuscatus Mots.	5	Westbank	board	April
Melanotus longulus oregonensis LeC.	2	Westbank, Summerland	board	June-July
Lathridiidae				
Lathridius minutus L.	1	Cawston	tray	June
Melandryidae				
Anaspis atrata Champion	3	Summerland	tray	June
Anaspis sp.	2	Kelowna, Summerland	board	June-July
Melyridae				
Anthocomus sp. nr. *nigrinus* Fall	2	Summerland	board	July
Eurelymis atra LeC.	1	Kelowna	board	June
Listrus sp.	1	Summerland	board	July
Malachius antennatus R. Hopp.	1	Summerland	board	June
Mordellidae				
Mordella atrata Melsheimer	5	Kelowna, Westbank, Summerland	board	July
Scarabidae				
Onthophagus nuchicornis L.	1	Summerland	board	Aug.
Tenebrionidae				
Coelocnemis californica Mann.	1	Westbank	soil at base of grapevine	Nov.
COLLEMBOLA				
Entomobryidae				
Entomobrya sp. perhaps *nivalis* (L.)	17	Oliver	tray	Aug.
Willowsia buskii Lubbock	7	Kelowna	tray	July
DIPTERA				
Ceratopogonidae				
Atrichopogon sp.	1	Oliver	tray	Oct.
Forcipomyia sp.	1	Summerland	tray	June
Chironomidae				
Ablabesymia sp.	2	Summerland	tray	Sept.
Chironomus sp.	1	Westbank	tray	Sept.
Dicrotendipes sp.	2	Westbank, Summerland	tray	Sept.
Micropsectra sp.	1	Westbank	tray	Sept.
Parachironomus sp.	1	Westbank	tray	Sept.
Phaenopsectra sp.	1	Summerland	tray	Sept.
Tanytarsus sp.	1	Westbank	tray	June
Dolichopodidae				
Chrysotus sp.	1	Kelowna	board	June
Drosophilidae				
Drosophila sp.	1	Summerland	tray	June
Ephydridae				
Philygria opposita Lw.	1	Summerland	tray	Sept.
Sciaridae				
Bradysia sp.	15	all areas	tray	June-Oct.
Conioscinella sp.	3	Summerland, Cawston	tray	July & Sept.
Thaumatomyia glabra var.	2	Kelowna, Oliver	tray	June & Aug.
EPHEMOROPTERA				
Baetis sp. ?	1	Westbank	tray	Aug.
HEMIPTERA				
Anthocoridae				
Orius tristicolor (White)	9	Kelowna, Westbank Summerland	board tray	June-Sept.

Lygaeidae				
Geocoris bullatus (Say)	1	Summerland	board	July
Nysius ericae (Schilling)	13	Summerland, Cawston	board	June-July
Rhyparochromus chiragra californicus Van D.	12	Oliver, Cawston	board	July-Aug.
Sphragisticus nebulosus (Fallen)	1	Summerland	board	Aug.
Miridae				
Campylomma verbasci (Meyer)	1	Kelowna	board	Aug.
Ceratocapsus sp.	1	Summerland	board	July
Deraeocoris (Camptobrochis) *brevis* (Uhler)	19	Kelowna, Oliver	board tray	July
Ilnacorella sulcata Kngt.	7	Westbank, Oliver	board	Aug.
Lygus columbiensis (Kngt).	1	Oliver	tray	June
Lygus desertus (Kngt.)	1	Oliver	tray	Aug.
Lygus elisus (Van D.)	1	Oliver	board	Aug.
Plagiognathus obscurus Uhler	2	Summerland	tray	July
Prepops sp.	1	Oliver	tray	Aug.
Nabidae				
Nabis ferus (Linn.)	67	all areas	tray	Aug.-Oct.
Neididae				
Neides muticus (Say)	2	Westbank, Oliver	tray	Aug.-Sept.
HOMOPTERA				
Aphididae				
Esigella sp.	5	Summerland	tray	Sept.
Cicadellidae				
Aceratagallia sp.	1	Missing when specimens returned from Ottawa		
Erythroneura ziczac Walsh	5000 +	all areas	tray, leaves, board	June-Oct.
Euscelidius schenki (Kirsch.)	1	Summerland	tray	June
**Helochara communis* Fitch	1	Vernon	board	Sept.
Osbornellus borealis DeL. & Mohr	1	Kelowna	tray	Sept.
Stenocoelidia lineata (Baker)	1	Summerland	tray	Aug.
Coccoidea				
Lecanium sp. prob. *coryli* L.	200+	All areas	leaves	July-Sept.
Phylloxeridae				
Phylloxera vitifoliae (Fitch)	450+	Kelowna, Westbank, Oliver	board	Aug.
Psyllidae				
Psylla pyricola (Forster)	1	Summerland	tray	Sept.
Psylla sinuata group	3	Oliver	board	Aug.
HYMENOPTERA				
Bethylidae				
Goniozus sp.	1	Summerland	tray	June
Braconidae				
Bracon xanthonotus (Ashm.)	1	Summerland	tray	Sept.
Lysiphlebus sp.	1	Kelowna	tray	Sept.
Orgilus sp	1	Summerland	tray	Oct.
Praon sp.	1	Summerland	tray	Sept.
Torymidae				
Torymus sp.	1	Summerland	tray	Oct.
Encyrtidae				
Aphycus maculipes How.	65	Oliver, Cawston	board, tray	Aug.
Aphycus sp.	1	Kelowna	tray	Sept.
Copidosoma bakeri How.	1	Oliver	tray	Aug.
Microterys sp.	1	Oliver	tray	Aug.
Ooencyrtus nr. *clisiocampae* (Ashm.)	1	Kelowna	tray	Aug.

Eulophidae				
Euplectrus platyhypenae How.	2	Summerland	tray	Oct.
Eurytomidae				
Harmolita sp.	1	Westbank	board	June
Figitidae				
Anacharis nr. *marginata* (Prov.)	1	Oliver	tray	Aug.
Ichneumonidae				
Campoletis argentifrons (Cress.)	2	Kelowna	board	June
Cremastus incompletus (Prov.)	2	Cawston	board	June
Diplazon laetatorius Fab.	1	Oliver	board	July
Itoplectis quadricingulata (Prov.)	1	Westbank	tray	Sept.
Mesoleiini	1	Oliver	board	Aug.
Stenomacrus sp.	1	Summerland	board	July
Symplecis sp	1	Cawston	board	June
Mymaridae				
Anagrus epos Girault	475	all areas	board	July-Sept.
Polynema sp.	1	Oliver	tray	Aug.
Platygasteridae				
Platygaster sp.	1	Kelowna	tray	June
Proctotrupidae				
Proctotrupes rufigaster Prov.	1	Cawston	board	July
Pteromalidae				
Habrocytus sp.	1	Summerland	tray	Sept.
Sphegigaster (poss. n. sp.)	1	Summerland	tray	Sept.
Scelionidae				
Telenomus sp. A + B	6	Oliver	board	July
Trissolcus sp. A	1	Kelowna	tray	June
Trissolcus sp. B	1	Westbank	tray	June
Trichogrammatidae				
Oligosita sanguinea sanguinea Girault	1	Oliver	board	July
LEPIDOPTERA				
Lyonetidae				
Bucculatrix sp. prob. *salutatoria* Braun	150	Summerland, Oliver Cawston	tray	Sept.
Lyonetia sp.	1	Oliver	tray	July
NEUROPTERA				
Chrysopidae				
Chrysopa oculata Say	1	Summerland	board	July
Raphidiidae				
Agulla adnixa (Hagen)	4	Summerland	board	June
PSOCOPTERA				
Psocidae				
Lachesilla pedicularia (L.)	12	Oliver, Cawston	tray	Sept.
Psocus sp. nr. *oregonus*	1	Summerland	tray	Sept.
THYSANOPTERA				
Thripidae				
Frankliniella tritici (Fitch).	9000+	all areas	leaves, board, tray	June -Oct.

RESULTS

A total of 122 species of insects representing 54 families was collected by the three sampling methods. Six of these species are grape pests in the Okanagan-Similkameen area but only one, the Virginiacreeper leafhopper, *Erythroneura ziczac* Walsh which causes leaf and fruit injury requires control measures. The grape phylloxera, *Phylloxera vitifoliae* (Fitch), although important in other grape growing regions, has not yet been determined to be an economic problem in British Columbia. Other potential grape pests which at present cause only minor injury and do not warrant control measures in British Columbia are the flower thrips *Frankliniella tritici* (Fitch); a lecanium

scale, *Lecanium* species probably *coryli* L., which may heavily infest grape vines (Phillips 1965); the black vine weevil, *Brachyrhinus salcatus* (F.) and the clickbeetle *Limonius infascatus* (Mots.).

Several predaceous insects were collected by each sampling method and two parasites were reared from their hosts, *Anagrus epos* Girault the egg parasite of the Virginia-creeper leafhopper and *Aphycus maculipes* How., which parasitizes *L. coryli.* Six species of Coccinellidae were collected including a *Stethorus* sp. which is predaceous only on mites. Other predaceous insects were three Hemiptera, *Neides muticus* (Say), *Nabis ferus (Linn.)*, and *Orius tristicolor* (White) which feed on thrips, aphids and other small insects; and two *Neuroptera. Agulla adnixa* (Hagen) and *Chrysopa oculata* Say, which attack a wide range of insects.

Five species of mites were found on the leaf samples. The twospotted spider mite, *Tetranychus urticae* Koch, and the European red mite, *Panonychus ulmi* (Koch), are potential economic pests. The other three species are mite predators with one, *Typhlodromus pyri* Scheuten, having been recorded only once previously in the Okanagan Valley (Downing and Moilliet 1971). Another phytoseiid, *Amblyseius andersoni* Chant found in 1974 on grape leaves from Westbank, had not been recorded previously in the Okanagan Valley (Chant and Hansell 1971).

The majority of insects collected from the boards and beating trays were not directly associated with grape plants, but originated from cover crops or native plants near vineyards. For example, 150 specimens of *Bucculatrix salutatoria* Braun whose host is the sagebrush, *Artemisia tridentata* Nutt., were taken from beating trays.

Vineyard pests not encountered in the 1972 survey are several species of cutworms, a Pulvinaria scale and the grape erineum mite, *Eriophyes vitis* (Pgst.). These pests have been found in separate isolated vineyards in the Okanagan-Similkameen area.

References

Chant, D. A., and R. I. C. Hansell. 1971. The genus **Amblyseius** (Acarina: Phytoseiidae) in Canada and Alaska. Can. J. Zool. 49(5): 703-758.

Downing, R. S., and T. K. Moilliet. 1971. Occurrence of phytoseiid mites (Acarina; Phytoseiidae) in apple orchards in central British Columbia. J. Entomol. Soc. Brit. Columbia 68: 33-35.

Phillips, J. H. H. 1965. Notes on species of **Lecanium** Burmeister (Homoptera: Coccoidea) in the Niagara Penninsula, Ontario, with a description of a new species. Can. Entomol. 97: 231-238.

WOOD BORER CONTROL IN SPRUCE LOGS WITH P-DICHLORO-BENZENE AND PLASTIC SHEETING (COLEOPTERA: CERAMBYCIDAE)

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ABSTRACT

Fumigation under plastic sheating of white spruce (**Picea glauca** (Moench) Voss) logs with crystalline p-dichlorobenzene (PDB) for 26 days killed more than 95% of cerambycid and other wood borer larvae under the bark and in the wood, at the lowest dosage of 8g of chemical per cubic meter of log plus air space volume. The long treatment-duration promoted the discoloration of logs by stain fungi. When treatments were shortened to 2, 4 and 7 days, and the PDB was dissolved in trichloroethylene, the lowest dosage at the shortest duration killed more than 80% of the wood borer larvae.

INTRODUCTION

The lumber industry has expressed growing concern over the degrading of lumber caused by wood borers in decked logs. Some methods of chemical preventative control have been published (Becker and Abbot, 1961, Ross and Downton, 1966, Gardiner 1970), and one study (Buffam and Lucht 1968) reported that excess heat in slash piles covered with clear polyethylene sheeting killed bark beetles under the bark. This paper reports the results of a pilot study testing the effects of fumigation with p-dichlorobenzene (moth balls), under plastic sheeting, on mortality of wood borer larvae under the bark.

METHODS

Two trials were made with borer-infested logs of white spruce *(Picea glauca* (Moench) Voss*)*, in a clearing at the Kananaskis Forest Experiment Station, Alberta. The logs were covered with 6-mil clear plastic sheeting and chemical placed under the covering. All logs were collected about 80 km W of Olds. They were less than one year old, and were severely infested with mature wood borer larvae.

In the first test crystalline p-dichlorobenzene (PDB) was used on fifteen log "decks", three for each of the following: a control, plastic covering only, plastic covering plus 8, 32, and 128 g of PDB per cubic meter of wood plus air space volume. The decks were about 0.6 m^3 in volume and consisted of three to seven logs each 67 cm long. Treatments began on 23 September 1968, and the decks remained covered till 19 October 1968, when all the fumigant of the largest dosage had evaoporated. Then all live and dead larvae under the bark and in the wood were removed, identified and counted. About one-tenth of the larvae classified as dead were kept at room temperatures for 24-48 hours to verify this.

In the second test dissolved PDB was used on one replicate each according to the experimental design of Table 2. Treatment decks were about 0.4^3 in volume and consisted of two 130 cm long white spruce logs, about 36 cm in diameter. Treatment began on 22 May 1969 and lasted 2, 4 or 7 days. The fumigant was dissolved in trichlorethylene[3] at the rate of 1 gm of PDB per 1 ml of solvent, distributed over the deck, and the deck then covered with plastic sheeting. The cover was removed after the prescribed duration and all dead and live larvae under the bark and in the wood were removed, counted and identified about 10 days after treatment.

RESULTS AND DISCUSSION

More than ninety percent of the wood boring insects present in all logs were *Tetropium parvulum* Casey (Cerambycidae). The larvae of other species present in decreasing numerical order were: Buprestidae— mainly *Melanophila* supp.; Cerambycidae-*Monochamus* spp., *Anoplodera* spp., *Acmeops* sp., *Tetropium cinnamopterum* (Kirby); and Melandridae-*Serropalpus* sp. Differential mortality among species apparently did not occur, and the data were therefore combined.

Crystalline PDB The fumigant in crystalline form gave effective control of wood borer larvae under the bark at all dosages (Table 1). The total mortality given in Table 1 includes a percentage of natural mortality, which is assumed to approximate the percentage mortality (20%) in the controls. Natural mortality was recognized by a brown discoloration of the

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[3] Supplied by Dow Chemical of Canada Ltd. of Calgary under the trade name of "Neu-tri".

TABLE 1—Mortality of wood borer larvae in three replications of white spruce log "decks" fumigated with granular crystalline p-dichlorobenzene for 26 days, under plastic sheeting.

Treatment	No. live wood borer larvae	No. dead wood borer larvae	Percent mortality
	Totals of three replications		
Control	265	66	19.9
Plastic sheeting only	378	138	26.8
8 g/m^3 of PDB	16	379	96.0
32 g/m^3 of PDB	7	305	97.8
128 g/m^3 of PDB	2	398	99.5

larvae, or by fungal growth on the dead larvae. Heat built up under the plastic apparently did not contribute appreciably to larval mortality in this experiment since mortality was also low (26%) in the plastic-only treatment. Crystalline PDB also penetrated into the logs or into the plugged larval tunnels, killing larvae in the pupal cells 10 cm in the log.

In all PDB treatments, live larvae were very sluggish compared to those in control and plastic-only logs. Bark beetle larval mortality was estimated at 60%, 90%, and 98% at dosages of 8, 32, and 128 g per m^3 of log deck, respectively.

Of special interest is that parasitic larvae, mainly Braconidae, exhibited a much greater tolerance to PDB than did the wood borer larvae. Mortality of parasites in cocoons could not be judged, but mortality of free parasitic larvae was negligible, except at the heaviest dosage, when it reached about 75%.

The high humidity and temperatures maintained under the plastic sheeting promoted severe discoloration of logs by blue-stain fungi, which would degrade lumber from logs treated in this way as much as would the "wormholes". It is therefore important that decks be covered with plastic for a short fumigation period only.

Dissolved PDB The dissolved fumigant treatments increased mortality of wood borer larvae compared to the control, at all durations (Table 2), but the total mortality was less than it was with crystalline PDB. Many live larvae were found where logs contacted the soil, indicating that the fumigant apparently did not penetrate these areas within seven days. Treated logs showed no perceptible increase in wood stain from fungi during treatment.

A treatment with only the solvent, which is slightly toxic, was not done. The addition of the solvent did not increase mortality appreciably, because the total mortality of chemical plus solvent was lower than that with crystalline PDB.

Since both the plastic and PDB are inexpensive compared to the value and volume of the logs treated, utilizing this chemicaal in liquid form may be feasible if applied in June or July when wood borer larvae are in the early stages of development, and have not yet bored into the wood. Estimated cost for insecticide and 6-mil plastic sheeting, based on a deck 5 m

TABLE 2 — Mortality of wood borer larvae in white spruce log "decks" fumigated with dissolved p-dichlorobenzene under plastic sheeting.

Treatment	2 days			4 days			7 days		
	No. live	No. dead	% dead	No. live	No. dead	% dead	No. live	No. dead	% dead
Control							42	12	22.2
Plastic sheeting only							11	10	47.7
8 g/m^3	8	62	88.6	15*	48	76.2	7	47	87.2
32 g/m^3	0	22	100	5	35	85.3	11*	24	68.6
128 g/m^3	1	28	96.7	0	27	100	9*	25	67.6

*Live larvae in portion of log in contact with soil.

wide, and 60 m long is 10¢ to 15¢ per 2.36 m^3 (=M bd. ft.) (1969 prices). If care is taken to prevent snagging and tearing, the sheeting can be reused, thus greatly reducing the cost of treatment.

A present PDB is one of the safest chemicals in use agains insects. Its ability to penetrate into wood and kill boring insects in a relatively short time may have wide application in the lumber industry.

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Résumé

La fumigation des billes d'Epinette blanche (*Picea glauca* (Moench) Voss) au p-dichlorobenzène (PDB) cristallin pendant 26 jours a tué plus de 95% des larves de perce-bois sous l'écorce des billes et dans le bois ' à la dose minimale de 8 g de produit chimique par mètre cube de bille plus volume spatial d'air. La longue durée du traitement a causé la décoloration des billes par des Champignons de décoloration. Les périodes de traitement ont été réduites à 2, 4 et 7 jours et le PDB a été dissous dans du trichloroéthylène. La dose minimale à la plus courte durée a tué plus de 80% des larves de perce-bois.

References

Becker, W. B., and H. G. Abbott. 1961. Prevention of insect damage to decked pine sawlogs in Massachusetts with BHC emulsion sprays. **J. Forestry 59:** 366-369.

Buffam, P. E., and D. D. Lucht. 1968. Use of polyethylene sheeting for control of Ips spp. in logging debris. **J. econ. Ent. 61:** 1465-1466.

Gardiner, L. M. 1970. New northern Ontario spruce beetle compels May start on log spraying. Canadian Forest Industries, July 1970.

Ross, D. A. and J. S. Downton. 1966. Protecting logs from long-horned borers with lindane emulsion. **For. Chron. 42:** 377-379.

BOOK REVIEW

Borden, J. H. and Herrin, B.D. 1972. *Insects in the Classroom.* B.C. Teachers' Federation, Vancouver. 147 pp. $3.50

Years ago this society discussed the idea of producing a school book on insects and even struck committees to investigate the problems. It is ironic that when a member independently authored such a book, the society as a whole appeared to be unaware of it. Another society has taken note, and with approval (see Bull. Ent. Soc. America 20(3) p. 218. 1974).

The book is a three-way collaboration. Professor Borden of Simon Fraser University supplied the basic knowledge; his co-author, a teacher in Vancouver, supplied the presentation; and the artist, Poul Neilson, supplied much of the interest. The Teachers' Federation and some named individuals also contributed. Physically, the book is 8½ x 7 inches, with paper covers, perforated pages and plastic spine, so that it lies perfectly flat when open. Some of the typography is open to criticism. Chapter and sub-heads in lower case letters with no capitals are followed by sub-sub-heads in large, block capitals. Both gimmicks are out of place, but perhaps the authors are not responsible. The line drawings range from adequate to excellent.

There are two parts. The first covers the necessary systematics, including four non-insectan Arthropod Classes and 22 Orders of insects. Each taxon is given one page on which is included: a line drawing of a typical representative; the derivation of its ordinal name and the common names; and characteristics, habits and importance in a paragraph apiece. Within the constraints of available space, these are very well done. Short chapters on metamorphosis, populations, and good and bad insects complete Part 1.

Part II is more ambitious, with longish chapters on collecting, rearing, experimenting and getting information, plus a bonus of three pages on possible and probable disasters. Little is missed that could possibly be included, except a note on avoiding otherwise inevitable damage by dermestids in collections. Experiments with choice chambers, temperature preferences, tasting and feeding in flies, soil insects, flight mills, nutrition, etc. are described with a maximum of ingenuity and a minimum of expense. Good directions are given for rearing *Drosophilia,* flour moths, blowflies, mealworms and locusts.

The last chapter (9) is a useful annotated list of biological supply houses, books, films etc., Provincial Entomologists and State Extension Directors. A detailed 8-page index completes this excellent, and for its avowed purpose, highly recommended book.

H. R. MacCarthy

THE EUROPEAN FRUIT LECANIUM, *LECANIUM TITLIAE* (L.) (HOMOPTERA: COCCIDAE), IN SOUTHWESTERN BRITISH COLUMBIA

by

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ABSTRACT

Lecanium tiliae normally has one annual generation in southwestern British Columbia. There was a partial second in a year following a mild winter. The heaviest infestations were on horse chestnut, Japanese plum, hawthorn, and maple, in that order. Hawthorn was damaged. The proportion of males tended to be higher in high than in low populations, and to decrease with increasing altitude. Severe winter cold caused marked population decreases and cold weather in June noticeable decreases. Natural enemies found in 1969-72 are listed.

The European fruit lecanium, *Lecanium tiliae* (L.) (formerly referred to as *L. coryli* (L.)), was introduced into southwestern British Columbia about 1903, probably from Holland (Lyne 1927). There were severe infestations in the Vancouver area in 1925-30, 1937-46, and 1964-72. The following observations on the biology and ecology of this scale were made in 1969-72, during a study of its natural enemies reported elsewhere (Rubin and Beirne 1975). They supplement observations by Glendenning (1925, 1931, 1933, 1934) and by Graham and Prebble (1953) on earlier infestations, and are based on collections of infested leaves or twigs.

Life-Cycle

There is normally one generation per year in British Columbia. The crawlers hatch from the eggs in May and feed on the leaves until late August when they become second instar larvae and migrate to the twigs and small branches, where they feed until September or October. Here they overwinter. No evidence could be found that they overwinter or fallen leaves, which sometimes happens in Europe (Krassilstchik 1915). The males appear early in April, after a pupation period of about a month. Egg-laying starts in May.

Host-Preferences

The lecanium scale feeds on various deciduous trees and shrubs. Regular surveys were made of the number of scales on leaves and on 50 cm of twig or branch, on six species of trees, selected as being common host-plants in the Vancouver area. A total of 241 random samples, containing 50,022 scales, were taken from the trees at different times. In addition, six selected samples, containing a total of 6,401 scales, were taken from heavy infestations on unidentified maple.

The average numbers of scales in the random samples of 50 cm of twig or branch were: horse chestnut 319 (17 samples); Japanese plum 81 (41); hawthorn 67 (48); maple 60 (29); black cherry 37 (25); and red alder 33 (15). Average on apple was 52 (3) and on sweet cherry 7 (2). The average for the selected samples from the heavy infestations on maple was 1,089 (6). The single most heavy infestation had 3,072 scales per 50 cm of maple branch.

Pest Significance

The scale becomes a pest by sucking juices from leaves and twigs of the trees and by producing honeydew that is a nuisance when it drops on cars and clothing and on which grows a black fungus or "sooty mould", *Fumago* spp., that inhibits photosynthesis.

Its pest importance is not always related directly to its population density. Trees such as horse chestnut that have large crowns suffer less damage than do trees with small crowns such as Japanese plum and hawthorn, even when horse chestnut has a more dense population than the others. Young trees are damaged most because they have the highest proportion of the young twigs on which the scales tend to concentrate. Hawthorn appeared to be particularly affected by scale attack in 1969-72: many infested twigs and small branches dried up and died; and infested leaves were usually smaller and sometimes thicker than non-infested ones. Tree damage in the 1925-30 infestation was sufficiently severe to warrant extensive

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spraying annually, which, incidentally, may have intensified that infestation by killing parasites of the scale.

Scales, especially males, were sometimes found trapped and drowned in the honeydew and in the secretions from the buds of some trees, notably of red alder.

Sex Ratio

In Europe males are usually rare, reproduction commonly is parthenogenetic, the sex ratio can be much influenced by climate, and the proportion of males decreases with increasing altitude (Thiem 1932). Glendenning (1925) found that males were much more numerous than females by about 3:1. In the present study, 19,359 scales were examined to determine their sex: 19.7% were males, or about 1:5.

There was wide variation in the proportion of males in scale populations on different host plants. It was above the average on Japanese plum (30%), horse chestnut and sweet cherry (27% each), but lower than the average on hawthorn (16%) and maple (14%, but 18% on the heavily infested trees), and much lower on red alder (8%) and black cherry (7%). In general, the proportion of males tended to be higher on hosts with high scale densities than on hosts with low ones.

Surveys of infestations at altitudes of up to 500 m indicated that, as in Europe, there is a decrease of 19% in the proportion of males with each increase of 100 m of altitude (significant at 5%). There was a decrease of 8% in the proportion of males with each increase of 10ºC (significant at 5%).

Influences of Weather

At times in 1969-70 scale populations, as indicated by numbers per 50 cm of branch, decreased markedly. Some of these decreases coincided with the occurrence of weather extremes, as follows:

There were decreases on three species of host plants between November 26 and December 31, 1971: from 307 to 122, 301 to 83, and 396 to 82 scales per 50 cm. December 1971 was very cold, with average temperatures of -0.6º and 0.6ºC at Burnaby Mountain and Vancouver Airport, respectively, as compared with the long-term winter monthly averages at those locations of 0.5ºC and 1.7ºC. Decreases on various host plants in the fall of 1970, from 31 to 7 between September 9 and 24, 62 to 12 between September 24 and October 8, 2,346 to 114 between November 15 and 21, coincided with a cold autumn and the beginning of a severe winter. There was also a decrease from 121 to 61 between February 1 and 16 and, on a similar plant, from 226 to 59 between March 3 and 12, both in the severe winter of 1970-71.

In 1971 a cold June was followed by a warmer than average July and August. Some scale populations decreased on various host plants from 133 to 35 between June 24 and July 15, 39 to 3 between June 30 and July 31, and 102 to 39 between June 30 and August 31.

The scale became active earlier than usual in the spring of 1970, following a very mild winter. This extension of its active period presumably was why there was an abnormal partial second generation in the fall of 1970.

It appears from these observations that temperature can be important in regulating scale populations.

Natural Enemies

The most important natural enemies in 1969-72 were the hymenopterous parasites *Blastothrix longipennis* (How.), *Metaphycus kincaidi* Timb., and *Coccophagus lycimnia* (Walk.). They are discussed elsewhere (Rubin and Beirne 1975).

The following is a list of the predators encountered:

Arachnida. Araneae (det. D. J. Buckle): *Araneus diadematus* Cl., *Araneus* sp., *Porhomma* sp., *Coriarachne brunneipes* Banks; Acarina (det. R. S. Downing): *Typhlodromus pyri* Scheut., *Amblyseius masseei* Nesb., *A. morgani* Chant, and various Tydeiade and saprophytic mites.

Insecta. Dermaptera (det. R. J. Lamb): *Forfiucula auricularia* L.; Hemiptera (det. G. J. Fields): *Anthocoris antevolens* White; Coleoptera (det. J. V. Richerson): *Chilocorus fraternus* LeC.; Neuroptera (det. K. H. Martin): *Hemerobius pacificus* Banks, *Hemerobius* sp. prob. *humulinus* L., *Chrysopa harrisii* Fitch.?, *C. carnea* Steph.?.

References

Glendenning, R. 1925. The lecanium scale outbreak in Vancouver, B.C. Proc. Ent. Soc. Br. Columb. 22:21-26.

Glendenning, R. 1931. The lecanium scale, an insect affecting fruit and shade trees on the Pacific coast. Canada Dept. Agric. Circ. No. 77. 4 pp.

Glendenning, R. 1933. A successful parasite introduction into British Columbia. Can. Ent. 65: 169-171.

Glendenning, R. 1934. On the control of **Eulecanium coryli** (L.) in British Columbia by the parasite **Blastothrix sericea** (Dalm.). Proc. Fifth pac. Sci. Cong., Canada 1933, 5: 3543-3545.

Graham, K. and M. L. Prebble. 1953. Studies on the lecanium scale, **Eulecanium coryli** (L.), and its parasite **Blastothrix sericea** (Dalm.), in British Columbia. Can. Ent. 85: 153-181.

Krassilstchik, I. M. 1915. (Report on the work of the Bio-Entomological Station (of Bessarabia) during 1914. Govt. of Bessarabia, Kishinev, 1915, 49 pp. In Russian) Abstract in Rev. Appl. Ent. 3: 395-398.

Lyne, W. H. 1927. **Lecanium coryli.** Spec. Publ. Calif. Dept. Agric. No. 73, p. 35.

Rubin, A. and B. P. Beirne. 1975. Natural enemies of the European fruit lecanium, **Lecanium tiliae** (L.) (Homoptera: Coccidae), in British Columbia. Can. Ent. 107: 337-342.

Thiem, H. 1932. Pleisozontie als Arterhaltungsprinzip. Jenaische Z. naturw. 67: 488-492.

NUMBERS OF *DENDROCTONUS RUFIPENNIS* (KIRBY) AND *THANASIMUS UNDATULUS* SAY AT PHEROMONE-BAITED POISONED AND UNPOISONED TREES

by

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ABSTRACT

Four times as many spruce beetles, *Dendroctonus rufipennis* (Kirby), were killed at spruce trees *(Picea engelmannii* Parry, *Picea glauca* (Moench) Voss) baited with frontalin and sprayed with insecticide than at trees baited but unsprayed. Many clerid predators, *Thanasimus undatulus* Say, were also killed at the baited and sprayed trees. Their numbers were correlated with those of killed spruce beetles. Other correlations show that sprayed and unsprayed trees were exposed to the same attacking spruce beetle population and that predation on the spruce beetles was occurring.

INTRODUCTION

A synthetic pheromone, frontalin (Kinzer *et al.*, 1969) causes aggregation in both sexes of spruce beetle *(Dendroctonus rufipennis* (Kirby)*)* and a clerid predator *(Thanasimus undatulus Say)*, when released from polyethylene capsules on living spruce trees *(Picea glauca* (Moench) Voss, *P. engelmannii* Parry*)* (Dyer, 1973). Insecticide sprayed onto the lower 3.0 m (10 ft) of tree boles kills all arriving insects, and thus prevents the establishment of galleries by spruce beetles and predation by *T. undatulus* (Dyer, 1973). Without insecticide, some arriving spruce beetles enter the bark of baited trees and attempt to reproduce, even though resistance by the tree may prevent subsequent egg hatching or development of brood. The predators, attracted to baited trees, arrive at about the same time as the first beetles, which gives them an opportunity for predation, which would probably not occur during natural attacks when some spruce beetles would have entered the bark before producing pheromone (Dyer, 1973). The following experiments carried out in 1973 and 1974 were designed to determine any differences in numbers of spruce beetles and predators at baited trees sprayed with insecticide, and the numbers of spruce beetles in baited, unsprayed trees.

METHODS

Near Prince George, B.C., 133 spruce trees, about 20.1 m (66 ft) apart in a line around a stand perimeter in the Naver forest, were baited with 1.0 ml of 1 part frontalin and 2 parts alpha-pinene, in May 1973. Two polyethylene capsules, containing the frontalin-pinene mixture, were placed on each tree on opposite sides at breast height. Every tenth tree was sprayed to drip with insecticide (lindane 0.5% in water) on the basal 3.0 m and was fitted with a wire-screen basket at the base (Dyer, 1973).

Collections from the baskets were made about twice a week, from June 14 to the end of August. In August, bark samples of 20.3 x 25.4 cm (8 x 10 inches) were removed from 25 trees randomly chosen out of the 91 attacked trees. A minimum of four samples was taken from each tree, one from each of the north and south aspects at breast height and at the base. If the attack height was greater than 1.8 m (6 ft) a further two samples were taken from the north and south aspects midway between breast height and attack height. The number of attacks, i.e. entrance holes, was counted for each sample.

In 1974, ten pairs of spruce trees were selected at about 403.3 m (1320 ft) intervals, in the Naver forest near the 1973 experiment.

Each pair had approximately the same dbh (±5 cm) and the trees were spaced about 20 m apart. Both trees of a pair were baited with frontalin and alpha-pinene, as was done in the 1973 experiment and one tree from each pair was sprayed with lindane and fitted with a screen basket as described. Screen baskets were also placed on seven of the ten unsprayed trees. Collections were made from all screen baskets about twice per week, from June 4 to August 28. Fragments of spruce beetles, such as pairs of elytra, were collected from baskets on unsprayed trees as evidence of arthropod predation.

At the end of the spruce beetle flight period in August, from five to 14 randomly distributed (20.3 x 25.4 cm) bark samples were removed from the unsprayed trees to obtain an estimate of the mean attack density. The estimated number of beetles was calculated by using the total attacked surface area of each tree, attack density, and the male to female ratio found in the sprayed-tree collections. Analysis of these data included three correlations: (1) between the number of spruce beetles and the number of *Thanasimus* caught on each date at the sprayed trees; (2) between the number of *Thanasimus* caught at each sprayed tree and the number of predator-killed spruce beetles at the corresponding unsprayed tree, and (3) between the number of spruce beetles caught at each sprayed tree and the estimated numbers under the bark of each corresponding unsprayed tree.

RESULTS AND DISCUSSION

In 1973, the average numbers of spruce beetles and *T. undatulus* killed per sprayed tree were 130.5 and 73.7, respectively. The average number of spruce beetles in the unsprayed trees was 43.5 (Table 1), or one-third the number killed at sprayed trees. At the sprayed trees, the ratio of *T. undatulus* to spruce beetles was 1 to 1.8.

TABLE 1. Numbers of **D. rufipennis** and **T. undatulus** caught at insecticide-sprayed and unsprayed trees baited with frontalin in 1973.

	No. of trees sampled	Mean no./ tree	Std. error of mean	%♂ [1]
Dendroctonus caught at sprayed trees	13	130.5	44.68	40.1±0.2
Thanasimus caught at sprayed trees	13	73.7	19.64	41.1±0.2
Estimated no. of **Dendroctonus** in attacked unsprayed trees	25	43.5	2.38	-

[1] 95% confidence belt

In 1974, the average numbers of spruce beetles and *T. undatulus* killed per sprayed tree were 1703.8 and 418.0, respectively. The average number of spruce beetles in the unsprayed trees was 395.7 (Table 2); about one fourth the numbers at sprayed trees. One *T. undatulus* was killed for each four spruce beetles on the sprayed trees, nearly half the ratio found previously. Fragments of spruce beetles were found in the screens on the unsprayed trees (Table 2), indicating that predation was occurring.

In the 1974 study, the follwing three pairs of variables were linearly related with significant ($P < .01$) correlation coefficients: (1) the number of *D. rufipennis* caught at sprayed trees and the number in unsprayed trees ($r=0.77$); (2) the number of *D. rufipennis and T. undatulus* caught at sprayed trees ($r=0.87$); and (3) the number of *T. undatulus* and the number of predator-killed *D. rufipennis* at paired trees ($r=0.88$).

Since the numbers of *D. rufipennis* at sprayed and unsprayed trees were significantly correlated, each of a pair of trees was exposed to the same or similar attacking populations. Therefore, some factor other than available population determined the difference in numbers at the sprayed and unsprayed trees. Since, at sprayed trees, the number of *T. undatulus* caught was correlated with the number of *D. rufipennis* caught and, at unsprayed trees, with the number of *D. rufipennis* destroyed, predation was one factor that reduced the number of beetles entering unsprayed trees. However, a precise count of the number of *D. rufipennis* killed by *T. undatulus* is difficult to obtain because some evidence of predation is lost in the bark crevices and spider webs on the tree boles; moreover, other insect predators may have killed attacking beetles. Table 2 shows that each *T. undatulus* would have had to remove about three spruce beetles to account for the reduced number in the unsprayed trees compared to those caught at the sprayed trees.

In 1974, the estimated ratio of predator to

TABLE 2. Numbers of **D. rufipennis** and **T. undatulus** caught at insecticide-sprayed and unsprayed trees baited with frontalin in 1974.

	No. of trees sampled	Mean no./ tree	Std. error of mean
Dendroctonus caught at sprayed trees	10	1703.8[1]/	274.21
Thanasimus caught at sprayed trees	10	418.0	95.73
Estimated no. of **Dendroctonus** in attacked unsprayed trees	10	395.7	85.92
Predator-killed **Dendroctonus** at unsprayed trees	7	15.8[2]/	2.57

[1]/ 44.4% ♂ ± 0.16% (95% confidence belt)

[2]/ Based on parts of **D. rufipennis**, such as pairs of elytra, in screen baskets at tree bases.

prey decreased from that of 1973, which should have resulted in a higher proportion of the arriving spruce beetles entering the trees, if predation were the only factor influencing attack density. However, the proportion was less in 1974 (0.23: 1) than in 1973 (0.33:1), indicating that some mechanism other than predation influenced the number of beetles entering the unsprayed trees. Nijholt (1973), studying another scolytid, *Trypodendron lineatum* (Oliv.), showed that the presence of males masked the secondary attraction of females. Hedlin[1] found that when using an insecticide on logs, the natural secondary attraction of *Trypodendron* females in the logs continued to attract other beetles longer and in greater numbers to treated rather than to untreated logs, presumably because the males were killed before they could join the females.

An anti-aggregative pheromone MCH (3-methyl-2-cyclohexen-1-one) is produced by spruce beetles after entering the host tree (Kline *et al.*, 1973; Rudinsky *et al.*, 1973). MCH repelled *D. rufipennis* from attractive host logs and felled trees when released nearby. Since it is probable that MCH was produced by the beetles after both sexes had entered the unsprayed trees, later arriving beetles in similar numbers would have been repelled from entering the unsprayed trees while the sprayed trees would have continued to be attractive throughout the flight period.

[1] A. F. Hedlin personal comminciation.

Résumé

Les auteurs rapportent que 4 fois plus de Dendroctones de l'Épinette, *Dendroctonus rufipennis* (Kirby), furent tués sur des Épinettes *(Picea engelmanii* Parry, *Picea glauca* (Moench) Voss) âppatees avec de la frontaline et arrosées avec un insecticide, que sur des arbes âppatés mais non arrosés. Plusieurs predateurs Clérides appartenant a *Thanasimus undatulus* Say, ont également eté tués sur des arbres âppatés et arrosés. leurs nombres ont été mis en corrélation avec ceux des Dendroctones. D'autres corrélations ont demontré que les arbres arrosés et non arroses ont egalement été exposés aux attaques par la même population de Dendroctones et que la prédation sur les Dendroctones avait lieu.

References

Dyer, E. D. A. 1973. Spruce beetle aggregated by the synthetic pheromone frontalin. Can. J. For. Res. 3: 486-494.

Kinzer, G. W., A. F. Fentiman, Jr., T. F. Page, Jr., R. L. Foltz, J. P. Vité, and G. B. Pitman. 1969. Bark beetle attractants; identification, synthesis and field bioassay of a new compound isolated from **Dendroctonus.** Nature 221: 477-478.

Kline, L. N., R. F. Schmitz, J. A. Rudinsy and M. M. Furniss. 1974. Repression of spruce beetle (Coleoptera) attraction by methylcyclohexenone in Idaho. Can. Ent. 106: 485-491.

Rudinsky, J. A., C. Sartwell, Jr., T. M. Graves and M. E. Morgan. 1974. Granular formulation of methylcyclohexenone: an antiaggregative pheromone of the Douglas fir and spruce bark beetles (Col., Scolytidae). Z. ang. Ent. 75: 254-263.

Nijholt, W. W. 1973. The effect of male **Trypodendron lineatum** (Coleptera: Scolytidae) on the response of field populations to secondary attraction. Can. Ent. 105: 583-590.

SOME CHIRONOMIDAE (DIPTERA) NEW TO BRITISH COLUMBIA AND CANADA

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During recent research on the chironomid fauna of saline lakes in the southern interior plateau region of British Columbia, a number of species new to Canada or British Columbia were encountered.

The following list cites those species that have been identified to date with certainty and gives the water bodies from which these insects have been taken in emergence traps. Species new to Canada are identified in the text by a double asterisk (**) and those new to British Columbia by a single asterisk (*).

The lakes studies are shown in Table 1 and are the same as those considered by Scudder (1969). Further details of the study area and the ecology of the chironomid species will be published later.

Family Chironomidae
Subfamily Tanypodinae
Tribe Macropelopiini
Subtribe Macropelopiina

**Derotanypus (Merotanypus) alaskensis* (Malloch)
B.C.—Barnes L., Round-up L., L. Lyle, Boitano L., L. Jackson, L. Greer, Rock L., Near Phalarope, Westwick L., Sorenson L., Near Opposite Crescent, Box 17, Barkley L., East L. and Box 27.
Previous records: Alaska, Yukon Territory, Northwest Territories, Alberta, Saskatchewan and Manitoba (Roback, 1971).

Subtribe Procladiina

**Procladius (Procladius) dentus* Roback
B.C.—Barnes L., Round-up L., L. Lye, Boitano L., Rock L., Westwick L., Sorenson L., Near Opposite Crescent, Barkley L. and East L.
Previous records: Alaska, Northwest Territories, Saskatchewan, Manitoba, Quebec and Labrador (Roback, 1971).

**Procladius (Procladius) clavus* Roback
B.C.—Barnes L., Round-up L., L. Lye and Boitano L.
Previous records: Spence Bay and Ceillini Lake, Northwest Territories (Roback, 1971).

Tribe Pentaneurini

**Ablabesmyia (Karelia) peleensis* (Walley)
B.C.—Barkley L., East L. and Box 27.
Previous records: Alberta and Ontario, Wisconsin and Iowa east to New York and south to South Carolina (Roback, 1971).

Subfamily Orthocladiinae
Tribe Orthocladiini

**Cricotopus abanus* Curran
B.C.—Box 17, Barkley L., East L., and Box 27.
Previous records: Manitoba (Sublette and Sublette, 1965; Sublette, 1967).

**Cricotopus flavibasis* Malloch
B.C.—Round-up L., L. Lye, Boitano L., L. Jackson, L. Greer, Rock L., Near Phalarope, Westwick L., Sorenson L., Near Opposite Crescent, Box 17, Barkley L. and East L.
Previous records: Alberta (Strickland, 1938) and Illinois (Sublette and Sublette, 1965).

**Cricotopus trifasciatus* (Meigen)
B.C.—L. Greer, Near Phalarope and Barkley L.
Previous records: Germany, Idaho, east to Ontario and New York, south to Missouri and Florida (Sublette and Sublette, 1965).

***Acricotopus nitidellus* (Malloch)
B.C.—a single male from Sorenson L.
Previous records: Illinois and New York (Sublette and Sublette, 1965; Sublette, 1970).

**Psectrocladius barbimanus* Edwards
B.C.—Barnes L., Round-up L., L. Lye, Boitano L., L. Jackson, L. Greer, Rock L., Near Phalarope, Westwick L., Sorenson L., Near Opposite Crescent, Box 17, Barkley L., East L. and Box 27.
Previous records: northern and western Europe and Stoughton, Saskatchewan (Saether, 1969).

***Psectrocladius zetterstedti* Brundin
B.C.—Box 27
Previous records: Sweden (Brundin, 1949). First record for North America.

Subfamily Chironominae
Tribe Chironomini

**Chironomus atrella* (Townes)
B.C.—one male from Sorenson L.
Previous records: Alberta to Prince Edward Island and south to California, Colorado and Massachusxetts (Sublette and Sublette, 1965).

**Einfeldia pagana* (Meigen)
B.C.—Barnes L., Round-up L., L. Lye, Boitano L., L. Jackson, L. Greer, Rock L., Near

Table 1. Location and characteristics of water bodies studied in the Cariboo and Chilcotin areas of British Columbia. Names in parentheses are those used by Scudder (1969).

Water body	Location		Area (ha)	Mean depth (m)	Max. depth (m)	Mean conductivity (microhmos/cm. at 25°C)
Barnes L* (Box 4†)	52°0'30''N	122°28'00''W	17.20	2.0	4.5	11816
Round-up L.* (Phalarope†)	52 02	122 30 30	30.84	2.6	6.2	6885
L. Lye* (Box 20-21†)	52 01	122 29 30	46.50	2.8	5.4	6548
Boitano L.**	51 57	122 08	80.70	2.7	4.5	4108
L. Jackson* (Nr. Opposite Box 4†)	52 00	122 27 30	5.83	1.4	2.3	2766
L. Greer* (Box 89†)	51 59 30	122 26	15.18	1.0	2.3	1602
Rock L.*	51 58	122 25	34.60	1.1	2.5	1496
Near Phalarope†	52 02	122 31	5.06	1.3	3.0	1334
Westwick L.**	51 59	122 09	58.32	1.3	4.5	1287
Sorenson L.††	52 00	122 10	-	-	-	-
Nr. Opposite Crescent†	51 59 30	122 27	6.88	1.4	3.3	810
Box 17†	51 59 30	122 26 30	2.67	1.1	3.3	741
Barkley L.* (Opposite Box 4†)	52 00	122 28	4.53	0.7	2.2	592
East L.* (Racetrack†)	51 59 30	122 26	27.03	1.9	6.5	372
Box 27†	51 59	122 25	4.30	0.5	1.5	16

**Official names cited in the Gazetteer of Canada. British Columbia Canadian Board of Geographical Names, Ottawa (1953).

* Official names adopted on the Chilcotin Training Area Composite Map MCE 120 (Edition 2). Mapping and Charting Establishment, Department of National Defence, Ottawa (1968).

† Unofficial names used by Scudder (1969). The "Box" series refer to duck nest boxes put up near the water body by the Game Branch of the B.C. Department of Recreation and Conservation in the 1950s: other names are convenience descriptive terms used for the water bodies by Scudder and his students over the years.

††Unofficial name used locally for the western half of the old Westwick L. which is now split into two by a road. The name Westwick L. as used here refers to the lake to the east of the road.

Note: Characteristics of water bodies taken from Scudder (1969) and Topping (1969).

Phalarope, Westwick L., Sorenson L., Near Opposite Crescent, Box 17, Barkley L., East L. and Box 27.

Previous records: Europe; Idaho, South Dakota, Michigan and New York (Sublette and Sublette, 1965). In Canada the only other record is from Saskatchedwan (Driver, 1971).

**Cryptochironomus psittacinus* (Meigen)

B.C.—Round-up L., L. Lye and Boitano L.

Previous records: Europe; Alaska to New York and south to Oregon and Kentucky (Sublette and Sublette, 1965).

**Cryptotendipes ariel* (Sublette)

B.C.—Barnes L., Round-up L., L. Lye and Boitano L.

Previous records: California (Sublette and Sublette, 1965).

Tribe Tanytarsini

**Tanytarsus gracilentus* Holmgren

B.C.—Barnes L., Round-up L., L. Lye and Boitano L.

Previous records: northern Europe, Alaska and Northwest Territories (Ellesmere Is.) (Sublette and Sublette, 1965).

***Tanytarsus holochlorus* Edwards

B.C.—Barnes L., L. Lye, Boitano L., Westwick L., Sorenson L., Box 17, Barkley L. and Box 27.

Previous records: Europe (Mundie, 1957).

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References

Brundin, L. 1949. Chironomiden und andere Bodentiere der Sudschwedischen Urgebirgsseen. **Rep. Inst. Freshwat. Res. Drottningholm** 30: 1-914.

Driver, E. A. 1971. Range extensions and habitat data of two Chironominae (Diptera:Chironomidae) from Saskatchewan. **Can. Ent.** 103: 1017-1019.

Mundie, J. H. 1957. The ecology of Chironomidae in storage reservoirs. **Trans. R. ent. Soc. Lond.** 109: 149-232.

Roback, S.S. 1971. The adults of the subfamily Tanypodinae (=Pelopinae) in North America. **Monogr. Acad. Nat. Sci. Philad.** 17: 1-410.

Saether, O. A. 1969. Some Nearctic Podonominae, Diamesinae and other Orthocladiinae (Diptera:-Chironomidae). **Bull. Fish. Res. Bd. Canada.** 170: 1-154.

Scudder, G. G. E. 1969. The fauna of saline lakes on the Fraser Plateau in British Columbia. **Verh. int. Ver. Limnol.** 17: 430-439.

Strickland, E. H. 1938. An annotated list of the Diptera (flies) of Alberta. **Canad. Jour. Res., Sect. D, zool. Sci.** 16: 175-219.

Sublette, J. E. 1967. Type specimens of Chironomidae (Diptera) in the Cornell University collection. **J. Kansas Entomol. Soc.** 40: 477-564.

Sublette, J. E. 1970. Type specimens of Chironomidae (Diptera) in the Illinois Natural History Survey collection, Urbana. **J. Kansas Entomol. Soc.** 43: 44-95.

Sublette, J. E. and M. S. Sublette. 1965. Family Chironomidae (Tendipedidae) in Stone et al. (ed.). A catalogue of the Diptera of America north of Mexico. **U.S. Dept. Agr. Handbook.** 276: 1-1696.

Topping, M. S. 1969. Giant chromosomes, ecology, and adaptation in **Chironomus tentans.** Ph.D. diss., University of British Columbia.

LIFE-CYCLE OF A SPIRAL GALL APHID, *PEMPHIGUS SPIROTHECAE* (HOMOPTERA: APHIDIDAE), ON POPLAR IN BRITISH COLUMBIA[1]

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ABSTRACT

Pemphigus spirothecae Pass. was inadvertently introduced into North America only recently. Upon hatching in spring on lombardy poplar, the fundatrix feeds on a leaf petiole, which bends and then spirals into a spiral gall. The fundatrix produces about 100 fundatrigeniae within the gall. These produce winged sexuparae which leave the gall and settle on the poplar bark, where they produce up to eight progeny, males and females. Each female lays a single large egg which overwinters on the bark. This aphid is thus monoecious and holocyclic.

INTRODUCTION

The gall aphid, *Pemphigus spirothecae* Pass., was studied on lombardy poplar, *Populus nigra* L. var. *italica,* on the campus of the University of British Columbia during 1973 and 1974. This aphid produces unique spiral galls (Fig. 1) on the petioles of the leaves. *P. spirothecae* is apparently common in Europe but was found only recently in North America in Quebec (Alleyne & Morrison 1974) and at about the same time in British Columbia. Its life-cycle in Europe has been described by Tóth (1939). The present stydy was undertaken to determine the life-cycle of the aphid in British Columbia and to describe the aphid-host plant interaction.

DEVELOPMENT OF THE GALL

In general, the formation of a gall has an early phase, a trophic phase, and a post-trophic phase (Mani 1964). In the spiral gall of *P. spirothecae* the early phase can be sub-divided into three stages: bending, spiralling and swelling (Gerhardt 1922); swelling of the gall continues through the trophic phase. Upon emerging from the egg, the fundatrix or stem mother, begins to feed on the petiole of a leaf producing first bending (Fig. 2b) then spiralling until three loose spirals have been produced (Fig. 2, c & d). Subsequent swelling of the gall seals the gall cavity and increases its size (Fig 2, e, f & g).

The time taken to produce the three coils on petioles of lombardy poplar outdoors at Vancouver was 3-4 weeks, considerably longer than the 6 days reported by Dunn (1960) for attaining the same stage in the laboratory. If the first instar stem mother dies while the gall is forming, no further development takes place and incomplete galls result with one or two coils. Subsequent feeding by the newly enclosed fundatrix stimulates the coils of the gall to grow laterally, sealing the walls. Increase in length of the coils expands the gall and increases the size of the cavity.

The galls reach maturity in late August and September, gradually changing from green to orange-red or brown. When mature, the galls measure about 15 x 13 x 9 mm. The gall cavity is lined by numerous short, papillate unicellular hairs, with some longer multicellular ones among them. When the gall is mature, one or two ostioles develop (Fig. 3) between the coils to serve as emergence holes for the aphids, or sometimes the coils loosen, producing a long slit in the gall, allowing a mass escape of the inhabitants. In this post-trophic stage, the galls deteriorate and fall from the tree with the leaves. The total life of a gall is from 20-25 weeks.

We could find no evidence that the presence of a gall on a leaf weakened the leaf or reduced its size. Galled leaves, however, fell from the tree sooner than non-galled ones.

LIFE CYCLE OF THE APHID

In late March or April at Vancouver the fundatrix emerges from the overwintered egg, at a time when the young poplar leaves begin to appear. The first instar fundatrix (Fig. 4) is small, brownish green, and has very well developed hind legs, 4-segmented antennae (Fig. 4a) and normally developed labium and stylets (Fig 5). In fact, its stylets are very much like those of *Myzus persicae* (Sulzer) (Forbes 1969) with each madibular stylet innervated by two dendrites. The fundatrix settles to feed on a leaf petiole, initiating the formation of the gall. The fundatrix moults for the first time as soon as the spiralling of the petiole has been completed, or almost completed i.e., about 3-4 weeks after hatching. After the fourth moult the fundatrix is mature and starts to reproduce parthenogenetically. The mature

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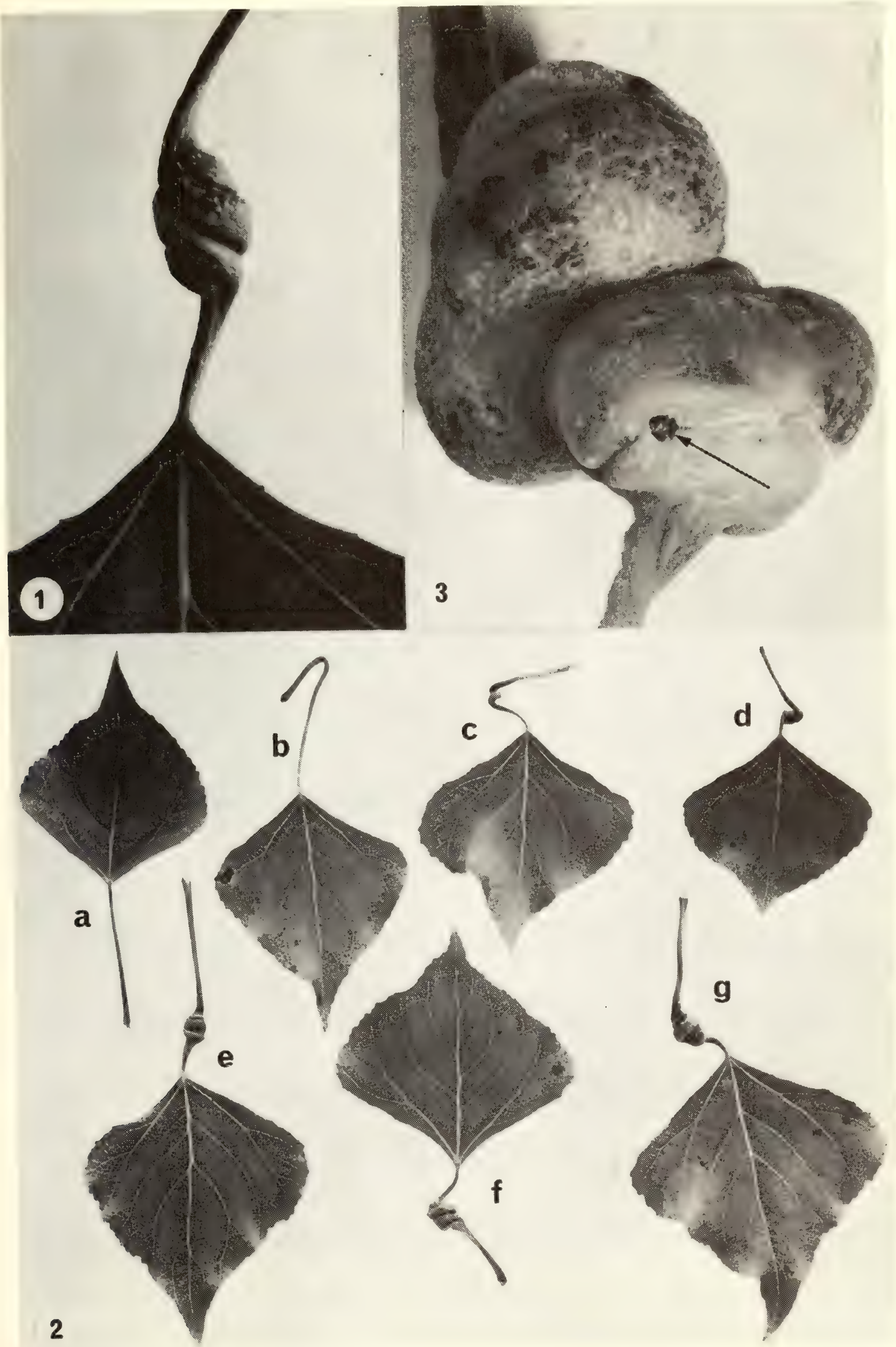

Fig. 1. Fully formed spiral gall of **Pemphigus spirothecae** Pass. on the petiole of a leaf of lombardy poplar.

Fig. 2. Stages in the formation of the gall: a, a non-galled leaf; b, bending of the petiole; c & d, spiralling of the petiole; e, f, & g, swelling of the gall.

Fig. 3 Mature gall with an ostiole (arrow).

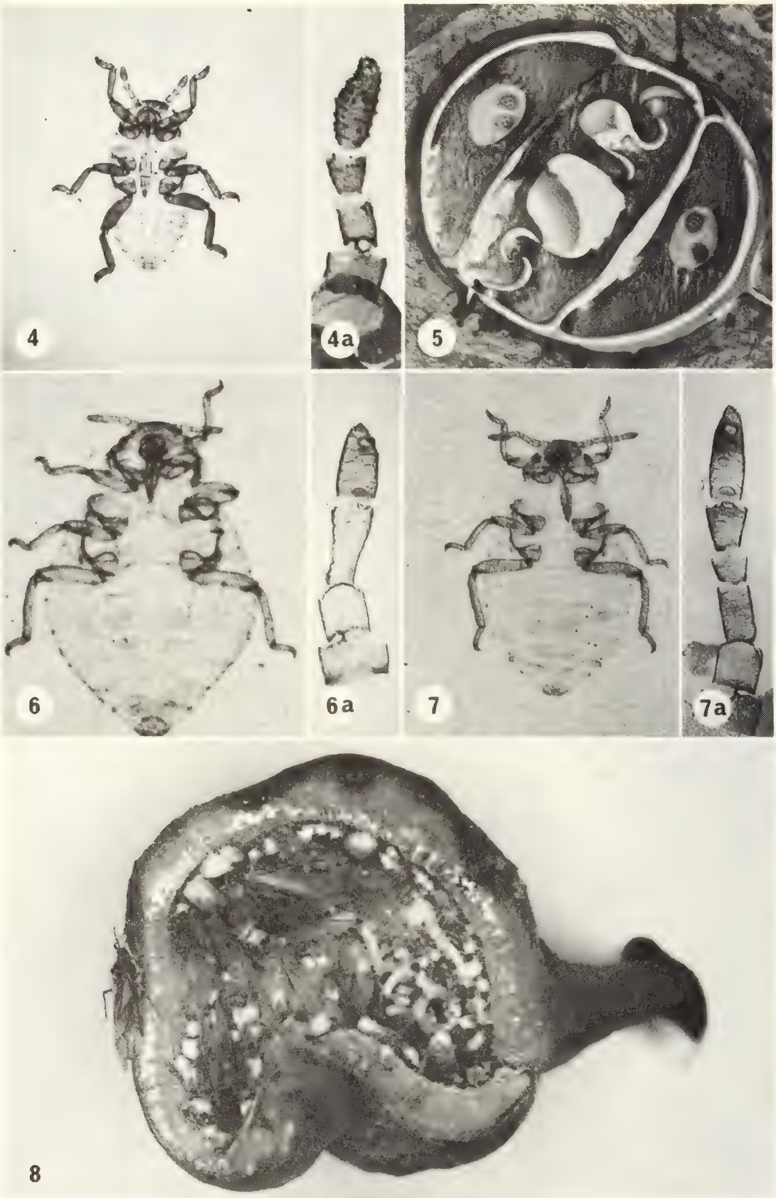

Fig. 4. First instar fundatrix of P. spirothecae with an enlargement of an antenna (4a).
Magnification: whole aphid = 0.5 mm
antenna = 0.1 mm

Fig. 5. Transmission electron micrograph of a cross section of the stylets of a first instar fundatrix. = 1 u

Fig. 6. Mature fundatrix with an enlargement of an antenna (6a).
Magnification: whole aphid = 1 mm
antenna = 0.1 mm

Fig. 7. Mature fundatrigenia with an enlargement of an antenna. Magnification as for Fig. 6.

Fig. 8 Sexuparae inside an opened gall.

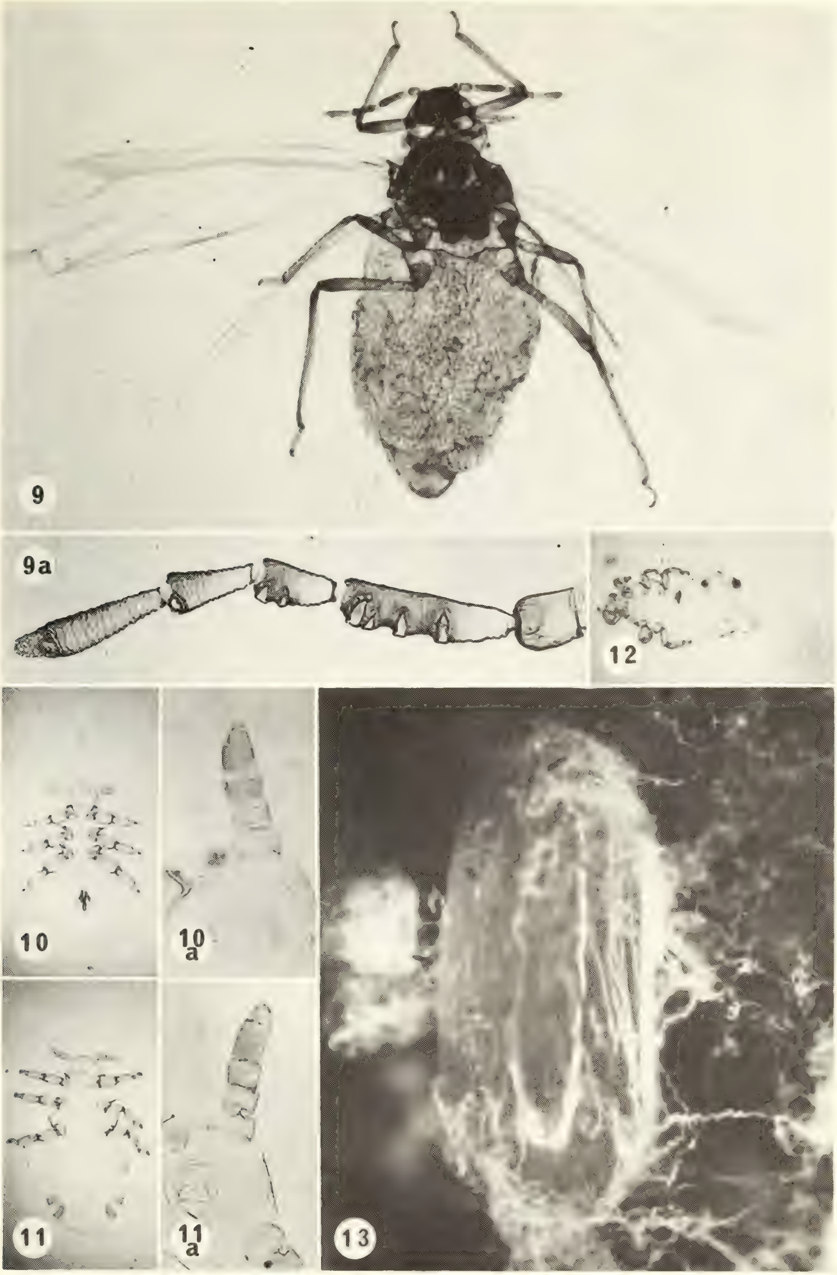

Fig. 9. Mature sexupara with an enlargement of an antenna (9a). Magnification as for Fig. 6.

Fig. 10. Mature male (sexuale) with an enlargement of an antenna (10 a). Note the rudimentary mouthparts. Magnification as for Fig. 6.

Fig. 11. Mature female (sexuale) with an enlargement of an antenna (11a). Note the rudimentary mouthparts. Magnification as for Fig. 6.

Fig. 12. Female laying her egg.

Fig. 13. An egg with wool-like wax.

fundatrix (Fig. 6) is pale yellow and has short 4-segmented antennae, (Fig. 6a) and well-developed labium and stylets.

At Vancouver the fundatrices mature between mid-june and the beginning of July. During July and August each fundatrix produces about 100 progeny, the fundatrigeniae. The mature fundatrigenia (Fig 7) is pale and can be distinguished from the mature fundatrix by its longer, 6-segmented antennae (Fig. 7a). The fundatrigeniae moult four times before they start producing the sexuparae.

The sexuparae are produced in August and September and are present in the galls (Fig. 8) from early August until lat November. The mature sexupara (Fig. 9) is winged and has 6-segmented antennae with transverse secondary sensoria on the third and fourth antennal segments (Fig. 9a). The head and thorax are black and the abdomen is yellow-green. Each sexupara produces a maximum of six females and two males on the bark of the tree and then dies. The females and males moult three times in a period of 36-40 hours and then mate. The male (Fig. 10) is small and pale green with 4-segmented antennae (Fig. 10a). The female (Fig. 11) is also small with 4-segmented antennae (Fig. 11a) but the abdomen is long and contains a single, very large egg (Fig. 12) which is laid in the crevices of the bark or under the lichen ***(Cetraria*** sp.) often found on the bark. The newly laid egg (Fig. 13) is 0.55 x 0.28 mm and is almost the size of the female's abdomen. It is white and covered by wool-like waxy secretions from the abdominal wax glands. In 3 or 4 days the egg changes to light green and then to a bright yellow-brown. The egg overwinters on the bark.

The sexuales do not feed since they do not have functional mouthparts. The labium is reduced to a small papilla and stylets are absent. The rudimentary condition of the mouthparts can be seen on the heads in the photomicrographs of the antennae in Figs. 10 and 11.

Thus all the morphs of *P. spirothecae* are found on the bark or in the galls on lombardy poplar. The aphid is therefore monoecious and holocyclic.

DISCUSSION

The formation of the spiral gall on the petiole of lombardy poplar is a dramatic example of the way in which aphids can change the growth processes of plants for their own advantage. The plant tissue completely surrounds and encloses the fundatrix and her progeny. Only late in the season does the gall open and release the sexuparae.

Other species of *Pemphigus* living on poplar produce markedly different galls. The form of the gall, therefore must be due to the specific feeding behaviour of the aphid when gall formation is initiated and to chemical substances injected into plants with the aphid's saliva (Miles 1968). The details of the feeding behaviour of the fundatrix of *P. spirothecae* have been described by Dunn (1960).

The spiral gall provides the aphid with an environment protected from parasites, predators and weather conditions; only the sexuales spend their entire life outside of the gall. Probably just as important to the aphid is the fact that the galling apparently supplies the aphid with improved nutrition by changing the physiology of the plant (Forrest 1971).

References

Alleyne, E. H., and F. O. Morrison. 1974. **Pemphigus spirothecae** (Homoptera: Aphidoidea), an aphid which causes spiral galls on poplar in Quebec. Canad. Ent. **106**(11): 1229-1231.

Dunn, J. A. 1960. The formation of galls by some species of **Pemphigus** (Homoptera-Aphididae). Marcellia **30** (Suppl.): 155-167.

Forbes, A. R. 1969. The stylets of the green peach aphid, **Myzus persicae** (Homoptera: Aphididae). Canad. Ent. **101** (1):31-41.

Forrest, J. M. S. 1971. The growth of **Aphis fabae** as an indicator of the nutritional advantage of galling to the apple aphid **Dysaphis devecta.** Ent. exp. & appl. **14** (4): 477-483.

Gerhardt, K. 1922. Über die Entwicklung der Spirallockengalle von **Pemphigus spirothecae** ander Pyramidenpappel. Z. Pflkrankh. **32:** 177-189. (Seen in Rev. appl. Ent. A10: 492 (1922)).

Mani, M. S. 1964. Ecology of plant galls. Monogr. Biol. **12.** Junk (The Hague).

Miles, P. W. 1968. Insect secretions in plants. Ann. Rev. Phytopathol. **6:** 137-164.

Tóth, L. 1939. Über die Biologie der Blattlaus **Pemphigus spirothecae** Pass. Z. angew. Ent. 26 (2): 291-311.

THE STATUS OF *CONOCEPHALUS FASCIATUS VICINUS* (MORSE, 1901) (ORTHOPTERA: CONOCEPHALIDAE)

by

JOHN E. R. STAINER[1]

ABSTRACT

It has been common practice to divide **Conocephalus fasciatus** (DeGeer, 1773) into two subspecies: **C. f. fasciatus** from eastern North America and **C. f. vicinus** (Morse, 1901) from the west. The criteria for this division are examined and evidence introduced to show that the name **vicinus** should be suppressed and that the entire taxon should be called **Conocephalus fasciatus** (DeGeer, 1773).

LITERATURE REVIEW

The name of this taxon has undergone many changes since DeGeer (1773) described a tettigoniid from Pennsylvania which he called *Locusta fasciata.* Thunberg (1815) set up the genus *Conocephalus* which was intended to include, among others, the "cone-headed grasshoppers" now placed in *Neoconocephalus* Karny, 1907, and the "meadow-grasshoppers" presently placed in the group. Audinet-Serville (1831) briefly described a genus, *Xiphidion,* which included among its species *Xiphidion fasciatum* (DeGeer). Burmeister (1839) emended the suffix so that the name of the genus became *Xiphidium.* These two names were thereafter used more or less interchangeably for the balance of the nineteenth century.

Kirby (1890) listed four references to *Xiphidion* and one to *Xiphidium.* A few authors, including Kirby (1906), used the name *Anisoptera* Latreille, 1829, for the same taxon. Rehn (1907) re-examined the situation and pronounced, as had Kirby (1906), that *Conocephalus hemipterus* Thunberg was identical with *Gryllus conocephalus* Linnaeus, 1758. As no other specias had previously been designated as type of the genus, this made *G. conocephalus* the type of the genus by tautonymy. Kirby had not accepted the tautonymic nomenclature. When Rehn and Hebard (1915a, 1915b) published their monograms on American species of the genus, the name *Conocephalus* became well established and it remains so to the present day. DeGeer's species is now known as *Conocephalus fasciatus* (DeGeer).

Xiphidium vicinum was described by Morse (1901) from the Pacific Southwest of the United States of America, as a species similar to *X. fasciatum* but with the ovipositor almost constantly longer than in the latter species. The ratio of hind femur to ovipositor was indicated as being greater than in *X. fasciatus.* Karny (1912) listed the two as separate species of *Conocephalus,* but Kirby (1906) had already recognized the two as full species, placing them in *Anisoptera,* presumably because of his lack of acceptance of tautonymic names, as noted above. The position of the "variety" *productum* of Morse (1901) remained confused, probably because of a lack of clarity in the original description. Karny (1907, 1912) considered this form to be a synonym of *C. fasciatus,* while Kirby (1906) and Rehn and Hebard (1915) both placed it under *vicinus,* which the latter authors further considered to be but a subspecies although he referred to *Conocephalus fasciatus* (DeGeer). The next author to devote much space to these members of *Conocephalus* was Cantrall (1943, 1968) who used the full trinomen of the eastern subspecies on both occasions, thus implying acceptance of the existence of another subspecies.

The ranges of the two groups were discussed by Rehn and Hebard (1915). Subsequent papers have made slight extensions in most possible directions. *C. f. fasciatus* was said to range over North America east of the Rockies and north as far as southern Canada. *C. f. vicinus* was considered to be restricted to the west: California, Oregon, Washington and the other American states to the west of the Atlantic-Pacific divide (except Alaska), and British Columbia.

MATERIALS AND METHODS

Only dried insects were used in this study. The measurements made were similar to those used by Morse (1901) as criteria for separating *fasciatus* from *C. vicinus.* Only females were used because Morse was unable to separate the males on morphological grounds. The measurements of the males have been made as part of another study but will not be discussed further in this paper.

The lengths of the ovipositor and one hind femur were recorded for each specimen. All measurements were made with a "Wild M5" stereo microscope equipped with a calibrated ocular micrometer. Measurements for reasonably-sized series of specimens from various individual localities were made and averaged

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and the ratio of femur III to ovipositor-length calculated. The ratios were then plotted on a base map of North America.

A separate set of measurements was made for all other available females (isolated specimens and very short series). These were grouped by state or province and averaged. The averages were plotted on the same map to provide an independent confirmation of the results from data obtained from the longer series.

RESULTS

The results are summarized in the accompanying map and table. The sample numbers (which were quite randomly designated) and localities follow: (1) Sainte Anne de Bellevue, Quebec, (2) Antelope Springs, California, (3) Eugene, Oregon, (4) Ames, Iowa, (5) Rock Co., Minnesota, (6) Scott Co., Minnesota, (7) Saint Anthony Park, near St. Paul, Minnesota, (8) Ottertail Co., Minnesota, (9) Republic, Anoka Co., Minnesota, (10) Rockaway Beach, Long Island New York, (11) Juniper, Florida, (14) South Ohio, Nova Scotia, (15) Avoca, Quebec, (16) Evans, Washington, (17) Gainesville, Florida, (18) Pequaming, Michigan, (19) Thomasville, Georgia, (20) Jemez Hot Springs, New Mexico, (21) Milford, Beaver Co., Utah, (22) Klamath Falls, Oregon, (23) Castlegar, British Columbia, (24) Malta, Montana, (25) Lac Serpent, Quebec, (26) Morgan Arboretum, Sainte Anne de Bellevue, Quebec, (28) Dorion, Quebec, (29) Point Pelee National Park, Ontario, (30) Sandbanks Provincial Park, Prince Edward County, Ontario, (31) Salmon Arm, British Columbia, (32) Saint Claude, Manitoba, (33) Delorraine, Manitoba, (34) Alexandria, Ontario.

DISCUSSION

An examination of the map (Fig. 1) reveals that the ratio of femur III to ovipositor reaches a maximum in California and a minimum in the north-eastern part of the range. With minor variations, which may probably be attributed

TABLE 1

Sample number	n	Ovipositor length (mm)	SD	Femur III length (mm)	SD	Ratio ovipositor/femur III
1	94	7.1	0.40	10.8	0.69	.66
1	94	7.1	0.40	10.8	0.69	.66
2	9	10.7	0.37	11.6	0.56	.92
3	11	8.6	0.30	11.4	0.51	.75
4	12	8.6	0.52	11.8	0.87	.73
5	14	9.3	0.57	11.6	0.64	.81
6	9	8.3	0.59	10.7	0.78	.78
7	10	8.6	0.49	11.4	0.35	.75
9	13	8,9	0,38	11,5	0,48	.77
10	11	7.4	0.55	11.8	0.74	.63
11	19	8.5	0.49	12.2	0.82	.70
14	13	7.6	0.36	11.6	0.39	.65
15	31	7.3	0.30	10.8	0.42	.68
16	7	9.4	0.99	11.3	0.37	.83
17	13	8.4	0.33	12.3	0.71	.68
18	16	8.6	0.37	11.8	0.64	.73
19	12	9.1	0.54	13.3	0.7	.68
20	8	9.0	0.44	11.2	0.4	.80
21	13	10.6	0.34	12.0	0.4	.88
22	8	10.3	0.27	11.4	0.56	.90
23	13	9.9	0.45	11.6	0.37	.85
24	4	8.8	0.36	11.8	0.66	.75
25	40	7.4	0.33	11.2	0.67	.66
26	24	7.7	0.28	11.7	0.59	.66
28	10	8.1	0.28	12.1	0.33	.67
29	24	7.8	0.55	12.2	0.71	.64
30	17	7.8	0.43	11.7	0.60	.67
31	15	9.2	0.28	11.5	0.32	.80
32	19	8.6	0.37	10.8	0.71	.80
33	8	9.4	0.71	11.5	0.55	.82
34	25	7.9	0.84	11.5	0.42	.69

Conocephalus fasciatus: sample size; lengths of femur III and ovipositor and their ratios. Sample numbers as in accompanying list of localities.

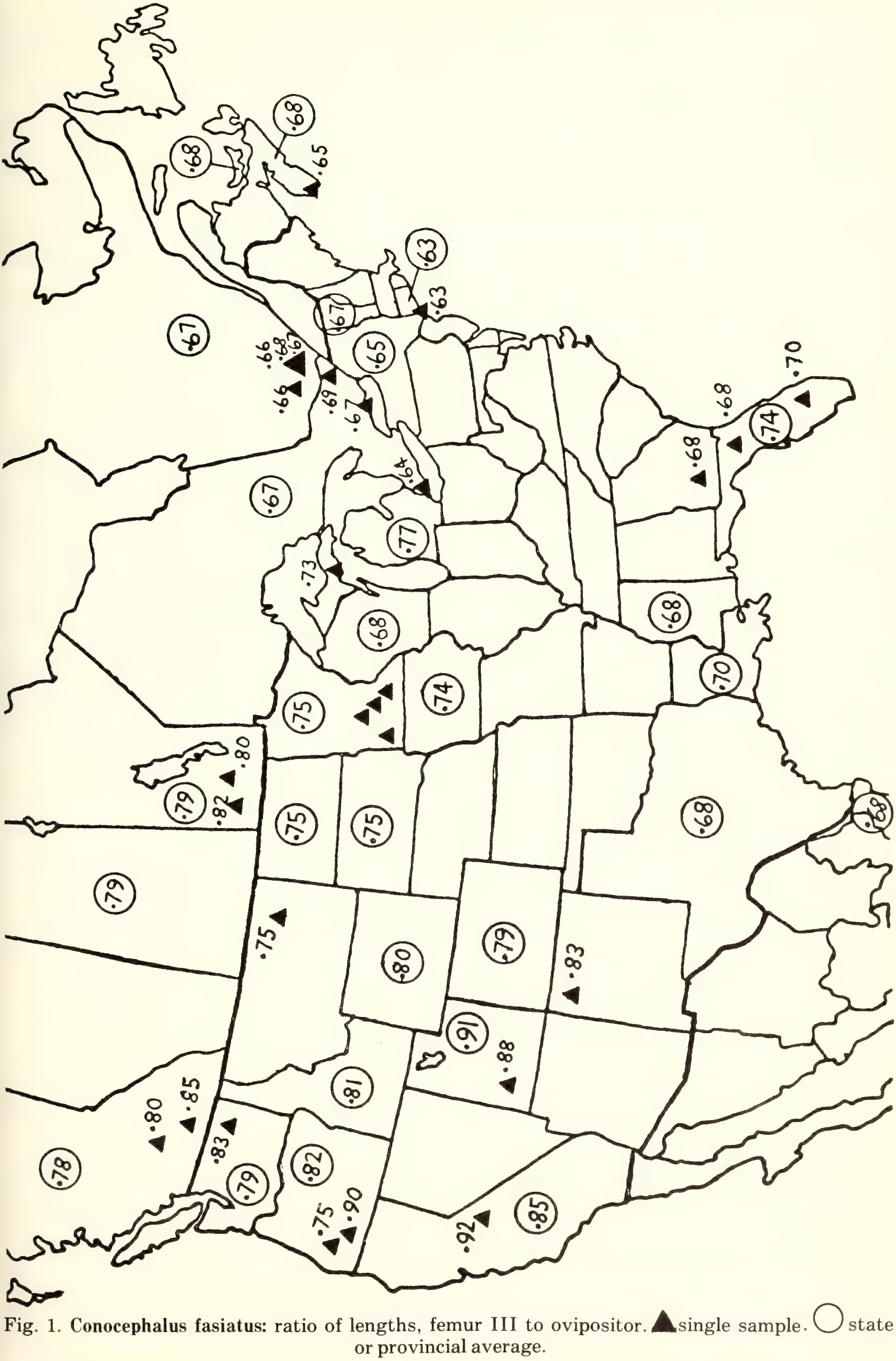

Fig. 1. **Conocephalus fasiatus:** ratio of lengths, femur III to ovipositor. ▲ single sample. ◯ state or provincial average.

to the small sample size, the ratio changes steadily between the two regions. Similar changes take place between California and British Columbia and between California and Mexico.

There were two independent sets of data as described above. the same pattern was found in the two separate sets of data, i.e., those from the long series and those grouped by state or province from individuals or short series. The pattern that emerged may be described as indicating a cline extending from a maximum ratio in California-Utah to minimum at the northern, eastern and, probably the southern limits of the range. The lowest ratios were found at the greatest distance from California; that is, in the northeastern portion of the range.

The existence of this cline calls into question the utility of Morse's name *vicinus*. Morse had examined material only from New England and California-Oregon and, apparently, nowhere between the two. he produced no usable criteria for the separation of males and was himself in many cases unable to distinguish between *vicinus* and *fasciatus* males. It should also be noted that, among other species of *Conocephalus*, it is the males that are most easily separated, the females often proving difficult. Morse was able to separate his females by use of the femur III/ovipositor ratio, but even this resulted in a "gray" area. A ratio of 0.50 to 0.67 was supposed to indicate *C. fasciatus*, while 069. to 0.95 was indicative of *vicinus*. Specimens between 0.67 and 0.69 mightbe regarded as belonging to either. In practice, the ratios do not appear to have been much used to separate the two taxa. Anything from east of the continental (Atlantic-Pacific) divide has been called *C. fasciatus* and that from the west has been called *vicinus*, either at the species or subspecies level. If one applies Morse's ratios to mid-western material, most specimens from west of Illinois would have to be called *vicinus* and there would be a very wide band of overlap with *fasciatus*. Thus it would be pointless to continue to recognize eastern and western entities as meriting separate names.

To end the confusion it is proposed to suppress the name *vicinus* althogether and to refer to the whole taxon as *Conocephalus fasciatus* (DeGeer, 1773) regardless of geographical differences.

ACKNOWLEDGEMENTS

A project of this type necessitates borrowing specimens from many sources. In this case thanks are due to the curators of about twenty different institutions in North America who lent material. In addition, the Entomology Laboratories of the Academy of Natural Sciences, Philidelphia, and of the Universities of British Columbia and Idaho, and of the Museum of Comparative Zoology, Harvard University, kindly permitted the use of their facilities. Financial assistance came in part from a grant from the National Research Council of Canada to Dr. D. K. McE. Kevan. Thanks are also owed to Dr. Kevan for reading and criticizing the manuscript and to Dr. T. J. Walker for collecting a series of specimens from Florida.

References

Audinet-Serville, J. G., 1831. Revue méthodique des insectes de l'ordre des Orthoptères; II. **Anns. Sci. nat. 22:** 135-167.

Blatchley, w. S., 1920. Orthoptera of Northeastern America with especial reference to the faunas of Indiana and Florida; The Nature Publishing Company, Indianapolis.

Burmeister, H., 1839. **Handb. der Ent.,** Berlin.

Cantrall, I. J., 1943. The ecology of the Orthoptera and Dermaptera of the George Reserve, Michigan; **Misc. Publs. Mus. Zool. Univ. Mich., 54:** 182 + X.

__________ 1968. An annotated list of the Dermaptera, Dictyoptera, Phasmatoptera and Orthoptera. **Mich. Ent. 1:** 9.

Geer, C. de, 1773. Mémoires pour servir a l'histoire des insectes, Stockholm.

Karny, H., 1907. Revisio Conocephalidarum. **Abh. zool. bot. Ges. Wein IV** (3): 1-114.

________, 1912. Genera Insectorum 135: 7-13.

Kirby, W. F., 1890. On the employment of the names proposed for genera of Orthoptera, previous to 1840. **Scient. Proc. R. Dubl. Soc. 6:** 556-597.

________, 1906. A synonymic catalogue of the Orthoptera. **Brit. Mus.** Longmans, London.

Morse, A. P., 1901. The Xiphidiini of the Pacific Coast. **Can. Ent. XXXIII:** 201 -205.

Rehn, J. A. G., 1907. Orthoptera of the families Tettigoniidae and Gryllidae from Sapucay, Paraguay. **Proc. Acad. nat. Sci. Philad.:** 370-395.

________ and Hebard, M., 1915a. A synopsis of the species of the genus **Conocephalus** found in North America north of Mexico. **Trans Am. ent. Soc. XLI:** 155-224.

________, ________, 1915b. VI—A synopsis of the species of the genus Conocephalus found in America south of the southern border of the United States. **Trans. Am. Ent. Soc. XLI:** 225-290.

Thunberg, C. P., 1815. Hemiptorum maxillosum, Genera Illustrata, Plurimusque novis speciebus ditata ac descripta. **Zap. imp. Akad. Nauk V: 218.**

BOOK REVIEW

Lamb, K. P. 1974. *Economic Entomology in the Tropics.* Academic Press, London, 195 pp. £4.00.

In this brave and successful book the publisher presents something of a puzzle. Well printed and illustrated on good quality paper, it is elegantly hard-bound in AP livery; but it is a small book which would fit into a paperback format no bigger than a thinnish Penguin. Even as a reference and teaching text it must surely soon be replaced by more detailed, regional texts. Perhaps, hopefully, the present hard-wearing library format means that it is a trail breaker and the forerunner of a series for graduate students and district agriculturists based on crops or insect groups or major regions. Any of these subdivisions is enough to absorb several lifetimes of research and review, but in a chauvinistic world, the last-named may be the most promising.

The organization by chapters is as follows: four pages on insects, good and bad; five pages on classification based on the *C.S.I.R.O.'s Insects of Australia* (1970); then short chapters on primitive and some aquatic insects; cockroaches and mantids; termites; Orthoptera and Dermaptera; Hemiptera; Lepidoptera; flies and fleas; beetles; Hymenoptera; the ecology of pest control; insecticides; malaria; and a summary of major pests of coffee, tea, cotton, cocoa, sugar cane, rice and coconuts. These, except for part of the rice crop, are cash crops and export items. Missing, except for passing mention, are pests of major local subsistence crops: bananas, citrus, cassava, pulses, millet, sorghum, mango, and maize.

The chapters on various orders include tables of selected pests, with common names, hosts, and distribution. Since keys are not possible, the tables exist in something of a vacuum, and become almost unmanageably long even when subdivided by hosts or groups of crops attacked. For instance, there are tables dealing with 50 Pyralids, 36 Noctuids, 31 scales, and 81 weevils; with distributions given as e.g.: the Americas, Africa, India, or even in desperation, pan-tropical. Prof. Lamb assumes considerable familitarity with scientific nomenclature. His English is clear and scholarly and by no means condescending or over-simplified. Mistakes, misspellings and misprints are at an irreducible minimum. The five to eight references with each chapter are carefully chosen. Most are generalized works, monographs and books rather than research papers. Eleven of the 97 are in French, four in German.

The dust jacket calls this: "A short, highly condensed, immensely practical book . . . the first broad review of economic insects in the tropics." As such it promises to be an invaluable starting point for problem solving, a teaching text, and the basis for more detailed successors.

H. R. MacCarthy

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CONTROLLING THE EUROPEAN WIREWORM, *AGRIOTES OBSCURUS L.*, IN CORN IN BRITISH COLUMBIA

A. T. S. WILKINSON, D. G. FINLAYSON
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ABSTRACT

Six insecticides at various rates and formulations, applied by three methods over three seasons, were evaluated for controlling the European wireworm, *Agriotes obscurus L.* in corn planted in silt loam. The insecticides were in granular form, applied as a broadcast, in a band, or in the seed furrow. Most of the materials, rates and methods gave good protection. Insecticide applied in the furrow was placed either in contact with the seed, or just ahead of it and mixed with soil. When it was in contact with the seed the yield was slightly lower, indicating some phytotoxicity. The furrow methods were the most economical in material and labour.

INTRODUCTION

Damage caused by wireworms to susceptible crops such as corn and potatoes is increasing in the lower Fraser Valley. The problem is serious in corn grown for the fresh market, canning and ensilage, especially near Agassiz where the wireworm *Agriotes obscurus L.* was accidently introduced from Europe about 1900 and has become well established (King *et al.* 1952; Wilkinson 1963). Much of the infested land in this area has been treated with the cyclodiene chlorinated hydrocarbons, aldrin and heptachlor, which gave protection for at least nine years following a single application (Wilkinson *et al.* 1964). Later tests showed that the small amounts of insecticide remaining in the soil were still toxic to young wireworms even 13 years after the soil was treated. In many fields the wireworms were eradicated by these chemicals but nearby headlands and road allowances provided a continuing source of reinfestation. Restoration of this wireworm to its previous levels is slow because the adults do not fly and the life cycle takes 3 to 4 years, so that an infestation may take several years to build up to economic levels. The worst problem at present involves land that was not cleaned up with the long-lasting chemicals of the late 1950s and early 1960s, but in time all the fields, treated or not, will need treatment.

A series of tests of short-lived insecticides and methods of application, were made during several seasons to find an effective, economic control. The most effective chemicals and the initial rates were determined in the laboratory and the field tests were done near Agassiz in silt loam.

MATERIALS AND METHODS

1970 Experiment: The land was infested with 80 *A. obscurus* per m² which destroyed corn planted in May. On June 10, insecticides were applied in randomized blocks replicated four times. The granular insecticides were broadcast evenly over the surface and worked in to a depth of 10 cm. Oats, peas, and vetch were planted since these crops can be grown successfully on heavily infested land. The effect of the treatment was determined in September

TABLE 1. Average numbers and percentage reduction of *A. obscurus* after broadcast soil treatments with various insecticides, Agassiz, B. C., 1970.

Insecticide	% granules	Toxicant (Kg/ha)	Wireworms/m²	Control (/)
Fonofos	20	5.6	12.16 a**	84.8
Carbofuran	5	5.6	12.16 a	84.8
Carbofuran	10	5.6	14.53 a	81.8
Bux*	15	5.6	19.37 a	75.8
Check		—	79.97 b	—

* A 3:1 mixture of m-(1-methylbutyl)phenyl methylcarbamate and m-(1-ethylpropyl) phenyl methylcarbamate.

** Values followed by the same letter are not significantly different (Duncan, 1955).

by counting the wireworms in 10 cylindrical soil cores taken at random from each plot with an augur. Each core was 103 cm^2 by 38 cm deep. The results are shown in Table. 1.

1974 Experiment: The population was 75.3 *A. obscurus* per m^2. Granular insecticides were applied in a band, in the furrow and by the broadcast method. The purpose of adding the band and furrow treatments was to reduce the amount of insecticide and thus the cost. Carbofuran was not included in the 1974 and 1975 experiments because of instability in some soils. Bux was withdrawn by the manufacturer.

In the band method the insecticide was applied in a strip 30 cm wide at 18.6 g toxicant per 100 m of row then worked into a depth of 10 cm. The corn was seeded in the middle of the band. In the furrow method the insecticide was applied with the seed at 9.3 g toxicant per 100 m of row. The treating and planting was done May 30. In September any differences in yield were shown by counting and weighing the corn stalks from 10 m of row. Wireworms were counted by sifting the soil and examining the roots in five samples per plot, each 15 cm square by 20 cm deep, dug with a spade, with a corn root at the centre of the sample. The results are shown in Table 2.

TABLE 2. Growth and yields of corn and average numbers of *A obscurus* per corn root after various treatments with four granular insecticides at Agassiz, B.C., 1974.

Insecticide	% granules	Method of Application	Toxicant (Kg/ha)	Avg. wt. plants (Kg)	Avg. no. wireworms/ corn root	Avg. no. stalks/ 10 m row	Avg. wt./ 10 m row (Kg)
Fonofos	10	Broadcast	5.6	1.04 a	.55 a	47.5 a	44.3 a
Counter[1]	15	Broadcast	5.6	1.03 a	.50 a	44.0 ab	40.1 ab
Fonofos	10	Band	2.0	1.02 a	1.40 ab	41.7 ab	37.9 ab
N 2596[2]	10	Broadcast	5.6	1.01 a	1.40 ab	41.2 ab	36.6 ab
Counter	15	Furrow	1.0	.96 ab	1.85 ab	45.0 ab.	36.5 ab
N 2596	10	Furrow	1.0	.93 ab	1.40 ab	46.7 ab	35.5 ab
Bay 92114[3]	10	Furrow	1.0	.92 ab	3.30 b	38.5 bc	32.2 bc
Fonofos	10	Furrow	1.0	.89 ab	.95 a	40.7 ab	31.3 bc
Bay 92114	10	Broadcast	5.6	.87 ab	1.50 ab	31.5 cd	23.6 cd
Check		—	—	.80 b	6.25 c	27.2 d	19.2 d

[1]AC 92100 S-([tert-butylthio] methyl) 0,0, diethyl phosphorodithioate
[2]S(p-chlorophenyl) o-ethyl ethane phosphorodithioate
[3]1 methylethyl 2 [[ethoxy[(1 methylethyl) amino] phosphinothioyl]oxy] benzoate

1975 Experiment: The methods of application were the same as in 1974 except for a modification of the furrow method. To determine if the insecticide applied with the seed caused phytotoxicity and reduced the yield, a second method was included whereby the insecticide was applied just ahead of the seed. Rates of 9.3 and 13.9 g of toxicant per 100 m were tested. The efficacy was determined by differences in the number of stalks, weight of the yield in 6 m of row and in wireworms counted by the method used in 1974. The treatments were made and the corn was planted May 13; it was harvested September 26. The wireworm counts were made September 30 and October 1. The results are shown in Table 3. The data were examined by analysis of variance and the results compared with Duncan's Multiple Range Test (Duncan 1955).

RESULTS AND DISCUSSION

Based on population counts the broadcast treatments of granules in 1970 all gave good control of wireworms (Table 1). There were no significant differences between the efficacy of the chemicals even in the two granular formulations of carbofuran.

In 1974 the results showed that in general the broadcast treatments were slightly better than the band or furrow treatments (Table 2). With the exception of the Bay 92114 broadcast treatment all the chemicals and methods gave significantly better yields than the control and all significantly reduced the number of wireworms. The furrow treatment of Bay 92114 was slightly, but not significantly, better than the broadcast treatment.

In 1975 all the treatments gave significant reductions in the number of wireworms over the control but the differences in yield were less clear, although significant differences were obtained. The broadcast treatments generally reduced the wireworm population more than did the furrow treatments. There were differences between the two furrow methods; most of the treatments in which the insecticide was applied with the seed had low yields, which indicated some phytotoxicity (Table 3). The heavy rate used in the furrow seemed to have little effect on yield but did give a greater re-

Table 3. Growth and yields of corn and average number of *A. obscurus* per corn root after various treatments with three granular insecticides, Agassiz, B.C., 1975.

Insecticide	% granules	Method of Application	Toxicant (kg/ha)	Avg. no. wireworms/ corn root	Avg. no. stalks/ 6 m row	Avg. wt./ (Kg/6 m row)
N 2596	10	Furrow*	1.8	.15 ab	30.5 abc	22.4 a
Counter	15	Furrow†	1.2	—	33.2 ab	21.8 ab
Fonofos	10	Broadcast	5.6	0.0 a	31.2 ab	21.4 abc
Fonofos	10	Furrow*	1.8	.5 abc	31.0 abc	20.9 abcd
Fonofos	10	Furrow*	1.2	1.05 c	29.7 abc	20.7 abcd
Counter	15	Furrow*	1.8	.15 ab	34.5 a	20.4 abcd
Fonofos	20	Furrow*	1.2	.55 abc	31.2 ab	20.4 abcd
N 2596	10	Broadcast	5.6	.1 ab	29.0 abcd	20.0 abcd
N 2596	10	Furrow†	1.8	—	27.5 abcde	19.9 abcd
Counter	15	Furrow*	1.2	.75 bc	28.5 abcde	19.5 abcde
Fonofos	20	Furrow†	1.2	—	24.0 cde	18.8 abcde
N 2596	10	Furrow*	1.2	.5 abc	31.2 ab	18.6 abcde
Counter	15	Broadcast	5.6	.3 abc	28.2 abcde	18.2 abcde
N 2596	10	Furrow†	1.2	—	26.5 bcde	18.2 abcde
Counter	15	Furrow†	1.8	—	28.0 abcde	17.6 bcde
Fonofos	10	Furrow†	1.2	—	26.5 bcde	17.2 cde
Fonofos	10	Furrow†	1.8	—	22.7 de	16.9 de
Untreated	—	—	—	2.25 d	22.0 e	15.5 e

*Insecticide applied ahead of the seed in the furrow.
†Insecticide applied with the seed.

duction in the number of wireworms than the low rate. Four months after application, dead and dying larvae were found in the plots treated by the furrow methods, which indicated that there was some persistence in the chemicals. Fonofos, N 2596 and Counter appeared to give about equal control regardless of method of application.

Over the years the broadcast treatments have given the greatest reduction in the number of wireworms and generally the best protection to the corn crop. The differences in control are not great but the cost of insecticide for the furow treatment is only ¼ that of the broadcast. Further savings are made because it does not require extra passes over the land to apply the insecticide or one or more additional diskings or rototillings to work in the insecticide. The band treatment requires about twice as much insecticide as the furrow treatment and does not have the advantage of easy application. The fact that wireworms were still being killed four months after the furrow treatments were made indicates that all the chemicals tested in 1975 remained toxic when in high concentrations in the soil. Thus, chemicals applied by this method will give protection during a growing season.

References

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics 11:1-42.

King, K. M. R. Glendenning and A. T. S. Wilkinson. 1952. A wireworm *(Agriotes obscurus L.)* Can. Insect Pest Rev. 30:269-270.

Wilkinson, A. T. S. 1963. Wireworms of cultivated land in British Columbia. Proc. Entomol. Soc. Brit. Columbia. 60:3-17.

Wilkinson, A. T. S., D. G. Finlayson and H. V. Morley. 1964. Toxic residues in soil 9 years after treatment with aldrin and heptachlor. Science 143:681-682.

HOMALOTYLUS CALIFORNICUS (HYMENOPTERA: ENCYRTIDAE(, A PARASITE OF *COCCINELLA CALIFORNICA* (COLEOPTERA: COCCINELLIDAE) IN BRITISH COLUMBIA

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ABSTRACT

We record the first occurrence in British Columbia of **Homalotylus californicus** Girault, a parasite of **Coccinella californica** larvae. Parasitized larvae are mummified and hardened with an abnormal bluish tint so they are easily recognized in the field. The rate of parasitization in the field was 13%. The significance of this and related parasites of Coccinellids is discussed.

In our study of the population dynamnics of aphids on oats and alfalfa, we made daily estimates of the abundance of coccinellids of all stages in our field plots. The procedure for estimating adult numbers will be reported elsewhere. When a pupa was encountered its species was recorded and a spot of paint was placed beside it to avoid confusion later.

In 1975, first generation pupae of *Coccinella californica* Mannerheim began to appear in mid-july. On July 30 an unusual larva was seen. It was moribund, hard, and mummified, but attached to a leaf at its caudal end. It looked like a larva about to pupate except for its dull bluish colour. Such 'blue' larvae were also identified with paint, and recorded separately. The last blue larva was found on August 19 at the end of production of pupae in the field.

In all, 30 blue larvae were taken. From six of these, emerged 5, 5, 5, 4, 3 and 3 adult *Homalotylus californicus* Girault, but the remaining 24 mummified larvae failed to develop further. When they were dissected, all contained dead parasite larvae oriented longitudinally more or less two abreast. Cocoons inside those larvae from which *H. californicus* had emerged were positioned similarly.

We recorded 201 normal pupae during the time when the 30 parasitized larvae were found. The rate of parasitization by *H. californicus* was therefore estimated at 30/(201+30) or 13%. This value cannot easily by compared to parasitization rates in the literature because of apparent inconsistencies in the use of names. The situation is similar to the confusion in use of two species names of *Homalotylus* in Europe (Hodek 1973); one species being solitary and the other gregarious. Muesbeck *et al.* (1951) and Peck (1963) refer to *H. californicus* as a subspecies of *H. terminalis* following Timberlake (1919) who did not find a constant diagnostic character to separate the two. But Leonard (1933) records that each pupa of *Cycloneda sanguinea* L. had a *single* emergence hole cause by *H. terminalis*, whereas our specimens had many holes, one for each adult parasite. Leonard recorded a parasitization rate for *C. sanguinea* as 90%; Kulman (1971) found that 26% of the *Anatis quindecimpunctata* larvae he observed were parasitized, each producing from 1 to 21 *H. terminalis;* and Kapur (1942), and Miller and Thompson (1926, 1927), recorded parasitization by *H. t. californicus* as high as 42%, and by *H. terminalis* up to 50%, respectively.

Yet in spite of the apparently low rate of parasitization we observed, we believe the *H. californicus* is potentially important. Preliminary field experiments on the survival of larval coccinellids show that less that 1% of newly hatched, first instar larvae survive to the fourth instar even when supplied with an abundance of prey. the 13% mortality caused by *H. californicus* is applied to those few surviving fourth instar larvae. Since the parasite is gregarious, the potential for increase and detrimental impact on *C. californica* is great, as shown by the high rates of parasitization reported for other gregarious species.

Homalotylus spp. have been considered by Hodek (1973) to be a very significant mortality factor which may limit the entomophagous efficiency of certain coccinellids in Europe, India, the U.S.S.R. and Israel. However, most species of *Homalotylus* are known to have parasites of their own; perhaps this accounts for their lack of more general and consistent impact.

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Literature Cited

Hodek, I. 1973. Biology of Coccinellidae, Junk, The Hague, 260 p.

Kapur, A.D. 1942. Bionomics of some Coccinellidae, predaceous on aphids and coccids in North India. Ind. J. Entomol. 4:49-56.

Kulman, H. M. 1971. Parasitism of Anatis quindecimpunctata by Homalotylus terminalis. Ann. Entomol. Soc. Amer. 64 (4):953-54.

Leonard, M. D. 1933. A braconid parasite of a Coccinellid new in Puerto Rico. J. Econ. Entomol. 26:294

Miller, R. L. and W. L. Thompson, 1926. Life histories of Lady-beetle predators of the citrus aphid. Florida Entomol. 10:40-46, 57-59.

Miller, R. L. and W. L. Thompson, 1927. Life histories of Lady-beetle predators of the citrus aphid. Florida Entomol. 11:1-18.

Muesbeck, C. F. W., K. V. Krombein and H. K. Townes, 1951. Hymenoptera of America North of Mexico. U.S.D.A. agr. Monograph 2, 1420 p.

Peck, O. 1963. A catalogue of the Nearctic Chalcidoidae (Insecta: Hymenoptera). Can. Entomol. Suppl. 30, 1092 p.

PREDATION BY CARPENTER ANTS: A DETERRENT TO THE SPREAD OF CINNABAR MOTH

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ABSTRACT

Cinnabar moth, an introduced biological control agent for tansy ragwort, suffers heavy predation by carpenter ants in recently logged areas of Oregon. We suggest that this mortality factor will reduce the spread of Cinnabar moth, thus preventing it from attacking a major seed source of tansy ragwort and reducing its potential as a biological control agent. Single larvae escape predation by ants more often than those in groups which suggests that carpenter ant predation may select for larval dispersal.

The Cinnabar moth, *Tyria jacobaeae* L. (Arctiidae), has been widely spread from its native Europe because of its potential as a biological control agent against the weed Tansy ragwort, *Senecio jacobaea* L. The success of these introductions has ranged from "never seen again" to "abundant and thriving" after 15 years. At Abbotsford, B.C. the failure of the first releases was attributed to heavy predation by ground beetles (Wilkinson, 1965). In the Gippsland vicinity of Victoria, Australia a mecopteran, *Harpobittacus nigriceps,* heavily predated a newly introduced Cinnabar population and a nuclear polyhedral virus assured the failure of the attempted introduction (Bornemissza, 1966). The causes for the lack of success of other introductions are not known (Hawkes, 1968, Harris *et al.* 1975, Isaacson 1973).

Van der Meijden (1971) records an almost perfect correlation between the log % mortality of Cinnabar larvae and log density of *Lasius alienus,* a predaceous ant. Further studies of *Lasius* predation led Van der Meijden (1973) to conclude that this ant may limit Cinnabar numbers in some sand dune areas of the Netherlands.

The following observations on predation by ants were made as a by-product of experiments designed to investigate larval dispersal in the Cinnabar moth.

Study Area and Methods

The study was carried out in Linn County, Oregon which lies between the western slope of the Cascade Mountains and the eastern edge of the Willamette Valley. Larvae were collected from the Silbernagel population which was studied by Isaacson (1973), and were transported to an area about 10 miles to the south on Neal Creek Road. This area was logged within the last 10 years so that stumps and fallen logs were abundant on the steep hillsides. Tansy ragwort is a common component of the herb-

TABLE 1. Survival after 2 days of 3rd and 4th instar Cinnabar larvae introduced to tansy ragwort plants in groups of approximately 20 individuals.

	Percent Survival				
	0-10%	11-25%	40%	65%	80-90%
Frequency	8	3	2	1	3
Total Survival = 98/329 = 30%					

aceous vegetation which has invaded this area, and moth populations occur sporadically along the road.

We chose the particular site for the study because while abundant, large ragwort plants occurred there, Cinnabar moth larvae were lacking. We placed third and fourth instar larvae on plants in groups of approximately 20 individuals, and recorded their movement from the central plant to surrounding plants.

Results

The disappearance rate of larvae from tansy ragwort plants was exceedingly high (Table 1). Observations revealed that the reason for this disappearance was the activity of carpenter ants, *Camponotus* sp., which nested in surrounding stumps. Ants were seen to attack and carry off the Cinnabar moth caterpillars but to verify that the high rate of disappearance was due to ant predation we set up groups of larvae on plants with the base coated with "stickum" which prevented ants from crawling onto the plants. The comparative rates of disappearance of larvae on ant-free plants and those to which ants had access are compared in Table 2.

TABLE 2. A comparison of Cinnabar larval survival on tansy ragwort plants to which ants had access and those which were ant-free. Larvae placed on plants in groups of 10.

	Plants Without Ants	Plants With Ants
Original Number	49	40
Number After 2 Days	43	9
Percent Survival	86	23

We observed that those Cinnabar larvae which dispersed from the original plant had better short term survival than those which remained behind (Table 3). The effect of group size was further tested by comparing the survival of single larvae to those in groups of 10. While the survival of these individual larvae was not as high as that of the natural dispersers (Table 3), it was almost double that of larvae in groups of 10 (Table 2) over a 2 day observation period.

Discussion

The relationship of the carpenter ant to the Cinnabar larvae is an interesting one. The Cinnabar larvae feed preferentially at the tops of the plants on the flower buds. Their feeding activity releases sap and the carpenter ants will feed beside the caterpillars taking the sap from the freshly cut surface. The two species have been observed to coexist in this way. However, suddenly an ant may attack a caterpillar. The usual result is that the caterpillar falls from the plant, sometimes taking its attacker with it. If other ants are nearby they too will join in the attack. On one occasion eight larvae lived two days on a plant that was occasionally visited by ants. Suddenly the attack began, and within one hour only three remained the others having been carried off

TABLE 3. Survival after 2 days of Cinnabar larvae which dispersed naturally from original tansy ragwort plants or were placed individually on plants.

	Larvae Dispersed Naturally	Larvae Placed On Individual Plants
Original Number	10	31
Number After 2 Days	9	13
Percent Survival	90	42

by the carpenter ants.

Tansy ragwort is common in Oregon on the extensively logged slopes of the Cascades and of the Coastal mountains to the West. Although in many areas Cinnabar moths have become established (Nagel and Isaacson, 1974) the presence of carpenter ants in this environment will undoubtedly influence the success of the natural spread of the moth to tansy ragwort areas. This will interfere with the attempt to destroy the source for tansy ragwort seed which these areas provide.

Predation by carpenter ants gives rise to a situation in which dispersal of Cinnabar larvae could be at a strong selective advantage. The general interpretation has been that in areas of high predation, survival of dispersing larvae will be low (Green, 1974). However, although larvae are exposed to predation while traversing from one plant to another, abandonment of the usual clumped distribution of Cinnabar moth larvae might make the difference between success and failure of establishment. If there is a genetic component to dispersal one might predict strong selection for dispersal in these areas.

References

Bornemissza, G. F. 1966. An attempt to control ragwort in Australia with the Cinnabar Moth, **Callimorpha jacobaeae** (L.) (Arctiidae: Lepidoptera). Australian J. of Zoology 14: 201-243.

Green, W. Q. 1974. An antagonistic insect/host-plant system: The problem of persistence. Ph.D. thesis. University of British Columbia.

Hawkes, R. B. 1968. The Cinnabar moth, **Tyria jacobaeae**, for control of tansy ragwort. J. econ. Ent. 61:499-501.

Harris, P., A. T. S. Wilkinson, M. E. Neary, L. S. Thompson, and D. Finnamore. 1975. Establishment in Canada of the Cinnabar Moth, **Tyria jacobaeae** (Lepidoptera: Arctiidae) for controlling the weed **Senecio jacobaea.** Can. Ent. 107:913-917.

Isaacson, D. L. 1973. A life table for the Cinnabar Moth, **Tyria jacobaeae**, in Oregon. Entomophaga 18: 291-303.

Nagel, W. D. and D. L. Isaacson. 1974. **Tyria jacobaeae** and tansy ragwort in Western Oregon. J. econ. Ent. 67: 494-496.

Van der Meijden, E. 1971. **Senecio** and **Tyria (Callimorpha)** in a Dutch dune area. A study on an interaction between a monophagous consumer and its host plant. Dynamics of Populations (P. J. den Boer and G. R. Gradwell, eds) (Oosterbeek, 1970): 390-404.

________________. 1973. Experiments on dispersal, late-larval predation, and pupation in the Cinnabar Moth (**Tyria jacobaeae** L.) with a radio-active label (^{192}Ir). Neth. J. Zool. 23: 403-445.

Wilkinson, A. T. S. 1965. Releases of Cinnabar Moth, **Hypocrita jacobaeae** (L.) (Lepidoptera: Arctiidae) on tansy ragwort in British Columbia. Proc. Ent. Soc. Br. Columbia. 62: 10-13.

CARABID AND STAPHYLINID BEETLES FROM AGRICULTURAL LAND IN THE LOWER FRASER VALLEY, BRITISH COLUMBIA

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ABSTRACT

Pit-traps were emptied every two or three days for two seasons in crop, fallow, and grass plots to determine the species and population density of Carabidae and Staphylinidae associated with agricultural land, and their relationship with brassica crops. Half of the plots were enclosed by plastic barriers and the beetles were trapped to extinction; half were not enclosed. Thirty-three carabid and 16 staphylinid species were captured. The dominant species was the small, generalized, European carabid predator, *Bembidion lampros,* which had a population on crop and fallow land of about 29000/hectare. It was almost absent in grass. Other numerous carabids were *Harpalus aeneus, Calathus fuscipes,* and *Clivina fossor,* all introduced European spp., with populations of almost 2000, 5600, and 11000/hectare respectively. The first and third of these were scarce in grassland but the second was abundant. In plots of Brussels sprouts *Aleochara bilineata,* a staphylinid, was effectively parasitic on root maggots, and averaged more than 6000/hectare. Soil cores taken in October centred on a Brussels sprouts plant averaged 26.4 *Hylemya* puparia per core of which 44% were parasitized by *A. bilineata.*

INTRODUCTION

In 1916 Gibson and Treherne reported several important parasites of root maggots. They included several species of Carabidae, which readily devoured eggs, larvae and puparia of *Hylemya brassicae* (Bouché) in the laboratory with other species of Staphylinidae which they believed to be predacious. Included also was the staphylinid *Baryodma ontarionis* Csy. (= *Aleochara bilineata* Gyll.) a well-documented parasite of the pupal stage of the cabbage root maggot, *H. brassicae.* Investigations of the biotic factors acting against root maggots (Wilkes and Wishart 1953) revealed a second staphylind parasite, *A. bipustulata* (L) which parasitized considerably fewer cabbage root maggots than *A. bilineata,* but was four times as abundant on seed-corn maggots *H. platura* (Meig.), a smaller host.

Wright (1956) and Wishart *et al.* (1956) demonstrated the importance of carabid and staphylinid beetles as predators of the immature stages of the cabbage root fly, especially of eggs. In 1960, Wright *et al.* exposed untreated crops to the first generation of the cabbage root fly and showed that predatory beetles could greatly reduce the root maggots and the crop damage. They discovered and Coaker confirmed (1965) that the principal predator in England was the small carabid, *Bembidion lampros* (Hrbst.). To determine which beetles were predators of eggs, Coaker and Williams (1963) trapped beetles at Wellesbourne, exposed them to cabbage root fly eggs, and identified the egg-feeding species by means of the precipitin test.

In 1972 and 1973, at Wellesbourne, England and Agassiz, B.C., Finlayson *et al.* (1975) examined the effects of several herbicides and insecticides on carabid and staphylinid beetles associated with minicauliflowers. The identity and numbers of beetles present in the treated and untreated plots were determined by pitfall trapping, a method discussed at length by Greenslade (1964). We investigated these predator populations in the lower Fraser Valley, mainly to determine their species and population density in agricultural land, and their relationship with cropping practices, especially in brassicas.

METHODS

The work was done at the Agriculture Canada Sub-station at Abbotsford. Three agricultural conditions were sampled: crop, fallow and grassland. In 1974 the plots were 400 m^2. Three of the plots were open so that the beetles could migrate freely, and three were enclosed by 4 mil black polyethylene barriers 15 cm high. The barriers were made by folding a strip of polyethylene, 60 cm wide, over a nylon cord, stapling the cord and polyethylene to 15 cm stakes about 2.5 m apart, and anchoring the bottom flaps by covering them with soil. In 1975, the plots were reduced to 100 m^2. There were 12 plots, two each of crop, fallow and grass enclosed by the barrier and two each left open.

The pitfall traps (pit-traps) were new tin cans, 7 cm diam x 11 cm deep. A hole, 2 cm diam, was cut in the bottom and covered with 40-mesh Lumite screen to allow rain water to drain while retaining the beetles. The pit-traps

were sunk in the ground with their rims level with the soil surface. After heavy rains the pit-traps were wiped clean around the upper 5 cm to remove accumulated dirt and ensure a smooth surface and thus to prevent the beetles from climbing out of the trap and escaping. In 1974 predation by birds, especially crows, *Corvus brachyrhynchos hesperis* Ridgway, in the pit-traps set in grass led us to insert a cone-shaped wire barrier of 1 cm mesh chicken netting, which allowed the beetles to enter but kept out the birds.

In 1974 there were 45 pit-traps in each 10 x 40 m plot, three rows of 15 traps spaced 2.5 m apart. Grass and fallow plots were sampled from April 26, but the cropped plots only from July 5 because barriers could not be erected until the Brussels sprouts crop, seeded June 17, was established. In 1975 each plot contained 16 pit-traps, evenly spaced throughout the plot, four in each of four rows, 2 m apart. The pit-traps and barriers were set in place in late March. Brussels sprouts plants were transplanted on April 1, and collecting started immediately.

The beetles were removed from the pit-traps usually on Monday, Wednesday and Friday of each week, identified and recorded. The beetles were identified in the field or if necessary submitted to the Biosystematic Unit in Ottawa for identification or confirmation. Beetles captured in the enclosed plots were released outside the barrier, but those captured in the open area were immediately released within the plot. Thus the total numbers captured in the enclosed area revealed the number per unit area, whereas those taken in the open area revealed their habitat preference and the cycle of the adult stage. The numbers of beetles of each species were recorded separately on each collecting period during the week, then summed to give a weekly total for each species.

Soil samples were taken from the Brussels sprouts plots at harvest in 1975 to determine the percentage parasitism of the overwintering population of puparia of *H. brassicae.* Ten samples were taken from each of the four plots of Brussels sprouts. Each sample, 15 cm diam x 12 cm deep, with the topped plant as the centre of the sample, was cut with a core sampler on October 7. The core was placed in a cardboard tub, 18 cm diam x 13 cm deep, sealed with a lid, placed in the greenhouse for 21 days to allow immature larvae to complete development, then stored at 3°C for 100 days to break diapause in *H. brassicae.* The puparia were recovered from the soil cores by floatation, placed in 30 ml bottles, and held at room temperature till the emergence of a fly or a parasite. Those puparia which did not produce either were dissected to determine if parasites were present but had failed to emerge.

RESULTS AND DISCUSSION

Thirty-three species of Carabidae and 16 species of Staphylinidae were taken from the pit-traps. They are listed alphabetically in accordance with Hatch (1953, 1957).

Carabidae

Amara apricaria (Payk.)
Amara californica Dej.
Amara familiaris (Duft)*
Amara obesa Say
Amara sp. (lunicollis group)
Anisodactylus binotatus (F)*
Agonum mulleri (Hbst.)*
Agonum subsericeum LeC.
Bembidion lampros (Hrbst.)*
Bembidion obscurellum Mots.
Bembidion petrosum Gebl.
Bembidion sp.
Blethisa oregonensis LeC.
Bradycellus congener LeC.
Bradycellus nigrinus Dej.
Calathus fuscipes (Goeze)*
Calasoma tepidum LeC.
Carabus granulatus L.*
**Carabus nemoralis* Müll.*
Clivina fossor (L.)*
Harpalus aeneus (F.)*
Harpalus opacipennis Hald.
Harpalus somnulentus Dej.
Leistus ferruginosus Mann.
Loricera decempunctata Esch.
Notiophilus nitens LeC.
Pterostichus adstrictus Esch.
Pterostichus lama Men.
Pterostichus vulgaris L.*
Scaphinotus marginatus Fisch.
Scaphinotus angusticollis Mannh.
Trachypachus holmbergi Mots.
Trechus obtusus Er.*

Staphylinidae

Aleochara bilineata Gyll.*
Aleochara montanica Cys.
Atheta sp.
Hyponygrus angustatus Steph.*
Lathrobium sp.
Megalinus linearis Ol.*
Morychus oblongus LeC.
Ocypus aeneocephalus DeG.*
Oxytelus rugosus (F.)*
Philonthus concinnus Grav.*
Philonthus fuscipennis (Mann)*
Philonthus varius Grav.*
Quedius curtipennis Csy.
Rugilus oregonus Csy.
Tachyporus chrysomelinus L.*
Tachyporus n. sp. near *chrysomelinus*
*Introduced species

Of the species captured, six carabids, *A. familiaris, B. lampros, C. fossor, H. aeneus, P. vulgaris* and *T. obtusus,* and two staphylinids, *A. bilineata* and *O. rugosus* are listed as predators of eggs of the cabbage root fly by Coaker

TABLE 1. Carabid and staphylinid beetles taken from pit-traps in crop, fallow and grass plots, enclosed by barriers at Abbotsford, British Columbia in 1974 and 1975.

	Number of beetles per hectare					
	Cropped		Fallowed		Grass	
	1974	1975	1974	1975	1974	1975
*Aleochara bilineata**	0	6200	75	25	0	0
Amara spp.	1550	5350	3225	4650	325	2400
Anisodactylus binotatus	25	550	700	400	100	400
Bembidion lampros	325	31100	16100	38500	275	650
Bembidion obscurellum	475	1950	1100	1850	0	0
Bembidion sp	25	0	350	0	1525	50
Calathus fuscipes	5875	550	7900	2800	9775	6800
Carabus nemoralis	50	0	25	100	100	50
Clivina fossor	175	15500	6400	10850	25	450
Harpalus aeneus	525	2000	4300	1600	325	150
*Megalinus linearis**	275	1000	2025	650	1650	15100
*Ocypus aeneocephalus**	0	50	0	150	1050	1450
*Philonthus concinnus**	100	950	375	250	300	3850
*Philonthus fuscipennis**	75	50	50	0	1275	1400
*Philonthus varius**	25	450	250	250	375	500
Pterostichus vulgaris	2275	1950	4625	700	500	700
Trachypachus holmbergi	0	600	125	650	0	50

*Staphylinidae

and Williams (1963). Although the smaller species feed on eggs and probably early instar maggots, the larger species of *Amara, Calathus, Harpalus, Pterostichus* and *Philonthus* are capable of feeding on third instar maggots and even of cracking the puparia.

Some species were considerably more abundant than others. At Abbotsford, 19 species (13 carabids and 6 staphylinids) appeared most frequently; the other 30 species were taken only occasionally.

The numbers of 19 of the common species trapped have been collated so that those from the barrier plots afford a reasonable estimate of the numbers of each species per hectare (Table 1). The numbers of the same species from the open plots show preferences for any of three habitats (Table 2). Because of the difficulty in separating the three common *Amara* spp. in the field *(apricaria, californica,* and *familiaris),* they have been grouped under *Amara* spp. All three species appeared in crop, fallow and grassland, and appeared to show only a slight preference for the cropped area.

The populations of Carabidae tended to be highest on cultivated land. *B. lampros, B. obscurellum, C. fossor,* and *H. aeneus* on crop and fallow land averaged approximately 35,000, 1,900, 13,000 and 1,800 respectively per hectare in 1975. These are very high numbers. The large species, especially *C. fuscipes* and *P. vulgaris,* were present in cultivated and sod land in comparable numbers. Conversely, the Staphylinidae appeared in greatest numbers in grass, with *M. linearis* the most common followed by *P. concinnus, O, aeneocephalus* and *P. fuscipennis. A. bilineata* appeared almost exclusively in the cropped area. Its numbers are directly dependent on the available numbers of its host, *Hylemya* puparia.

When the numbers of beetles from the barrier plots (Table 1) are compared with those from the open plots (Table 2), it is obvious that the increase in numbers results from recapture of the same beetle. The numbers of the larger species of beetles tended to be more uniform from year to year.

Of the 19 species most commonly captured, six were examined in greater detail to establish the period of greatest frequency, the number of generations per year and the adult cycle in relation to generations of root maggots. The data tabulated as weekly totals were plotted to show the numbers captured per week in barrier (Fig. 1) and open (Fig. 2), plots.

B. lampros and *C. fossor* were collected in early spring, i.e. late March and very early April. The peak of the cycle for *B. lampros* in both years (Fig. 2a, 2g) centered around the last week of May and the first week of June. It coincided well with the heavy oviposition of the first generation of the onion fly *H. antiqua* (Meig.), and the cabbage root fly. *C. fossor* (Fig. 2d, 2j) was present at an early date but in much smaller numbers. This species is consider-

TABLE 2. Carabid and staphylinid beetles taken from pit-traps in crop, fallow and grass plots, not enclosed by barriers at Abbotsford, British Columbia in 1974 and 1975.

	Number of beetles per hectare					
	Cropped		Fallowed		Grass	
	1974	1975	1974	1975	1974	1975
*Aleochara bilineata**	300	4550	25	250	0	0
Amara spp.	11075	8500	4375	4500	350	2800
Anisodactylus binotatus	25	1800	400	1350	375	950
Bembidion lampros	1500	108250	38950	73250	450	850
Bembidion obscurellum	975	7650	2475	16300	0	0
Bembidion sp.	0	50	125	50	3175	300
Calathus fuscipes	47250	26800	18150	13550	29750	29900
Carabus nemoralis	75	0	75	0	1175	700
Clivina fossor	50	3400	3850	4500	250	500
Harpalus aeneus	3450	26000	28100	21100	350	750
*Megalinus linearis**	525	1400	1900	550	3350	15650
*Ocypus aeneocephalus**	125	50	375	0	1450	2400
*Philonthus concinnus**	75	1100	100	500	625	6600
*Philonthus fuscipennis**	75	150	175	200	1600	2950
*Philonthus varius**	25	400	125	100	175	800
Pterostichus vulgaris	7225	1050	2300	500	6550	3100
Trachypachus holmbergi	0	5850	275	4300	0	50

*Staphylinidae

ed beneficial as a predator of eggs of root maggots, but it is also listed as a minor pest, causing damage to corn seed similar to that caused by wireworms (Tsinovskii 1961). Some of the larger species including *H. aeneus*, *H. rufipes* (found in eastern Canada), and *P. vulgaris*, have also been reported to feed on strawberry fruits (Briggs 1957).

C. fuscipes (Fig. 1c,i and 2c,i) was much more numerous in 1974 than it was in 1975. It peaked late in the year. Specimens were taken from April through October, but the greatest number coincided with the oviposition of the third generation of cabbage root fly. Its ability to feed on mature maggots and puparia could assist considerably in reducing over-wintering populations.

Amara spp., *B. obscurellum* and *H. aeneus* were generally common at the beginning of the growing season but were still present over the full period of trapping. *H. aeneus* showed a tendency towards a spring emergence period (Fig. 1e,k) but the *Amara* spp. were most numerous in late summer and fall (Fig. 2f,l).

From the soil cores taken in October 1975, 20 plants within the barrier plots yielded 432 puparia and 20 plants in the open plots yielded 623. *Hylemya* flies emerged from 52.5% and 50.6% of these respectively. From the puparia from the barrier plots which did not produce flies 193 *A. billineata*, 44.7%, and 12 (2.8%) cynipid wasps, *Trybliographa* probably *rapae*, were recovered. From the puparia from the open plots which did not produce flies 267 (42.8%) *A. bilineata* and 41 (6.6%) *Trybliographa* were recovered. It is important to note that the 40 plants sampled averaged only 26.4 puparia each and that these plants, transplanted on April 1, withstood the attack of three generations of root maggots without the protection of pesticides. For that reason it is essential that research be continued to develop chemical controls for brassica crops which are not detrimental to the parasites and predators of the root maggot complex.

ACKNOWLEDGEMENT

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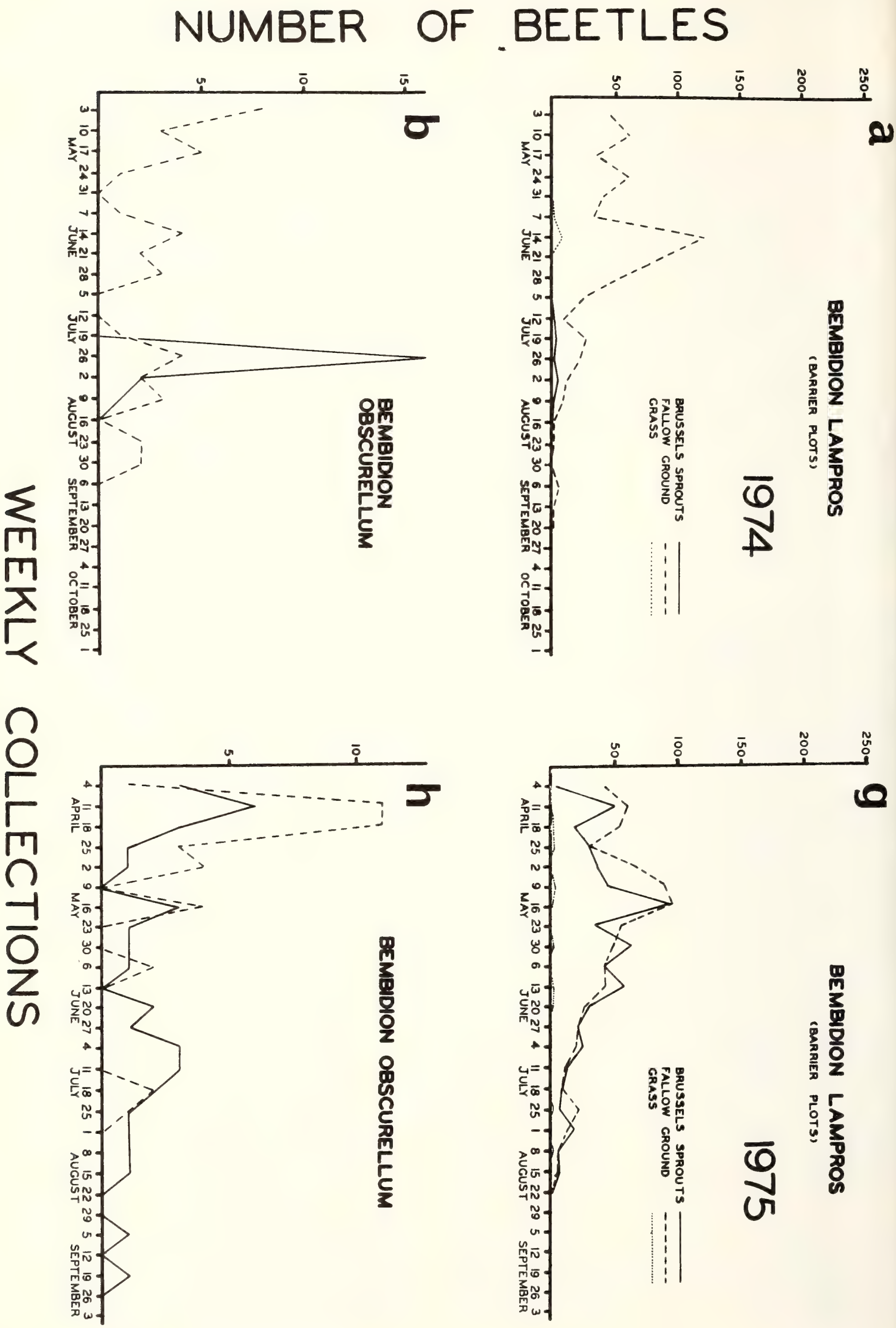
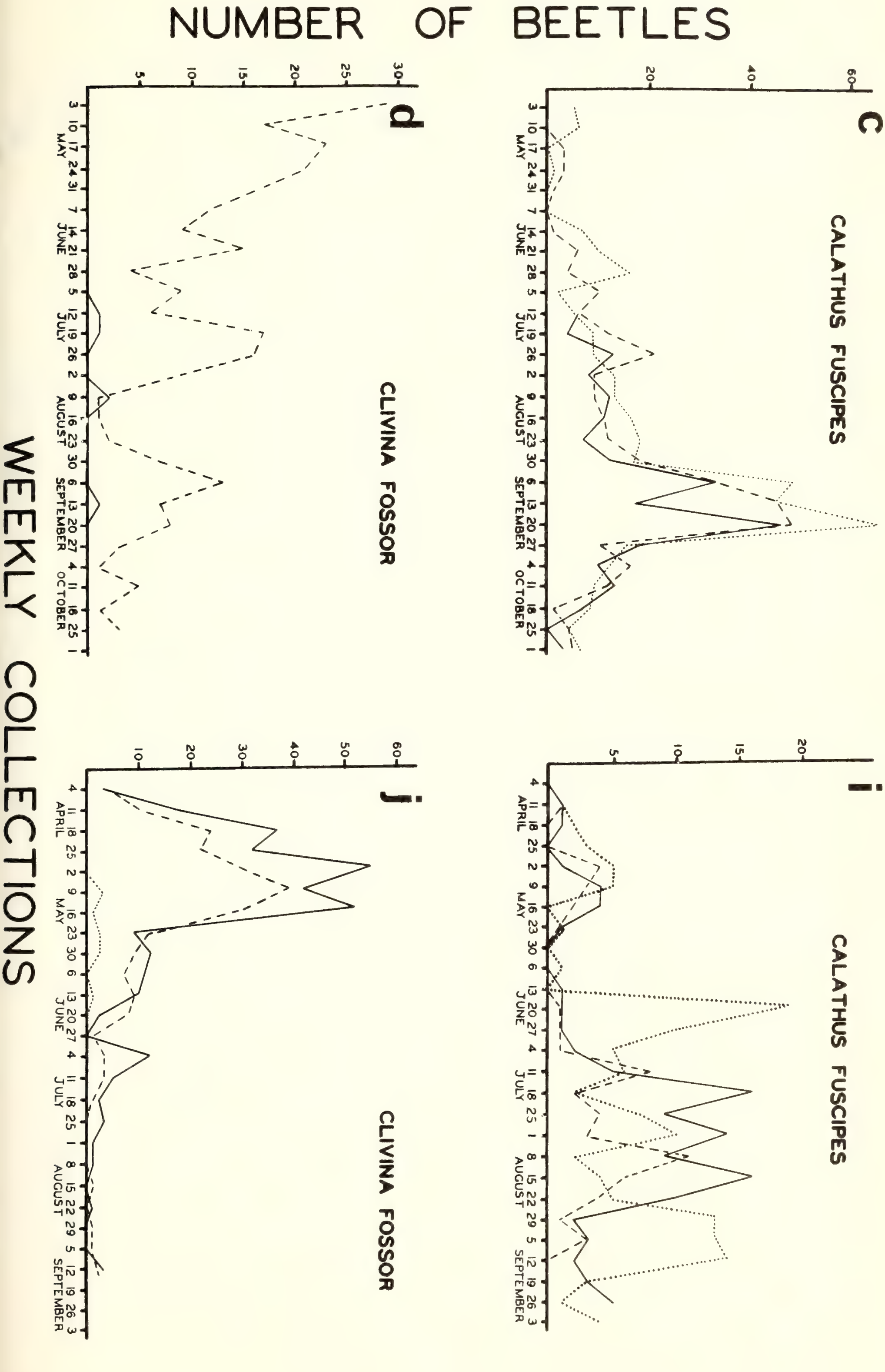
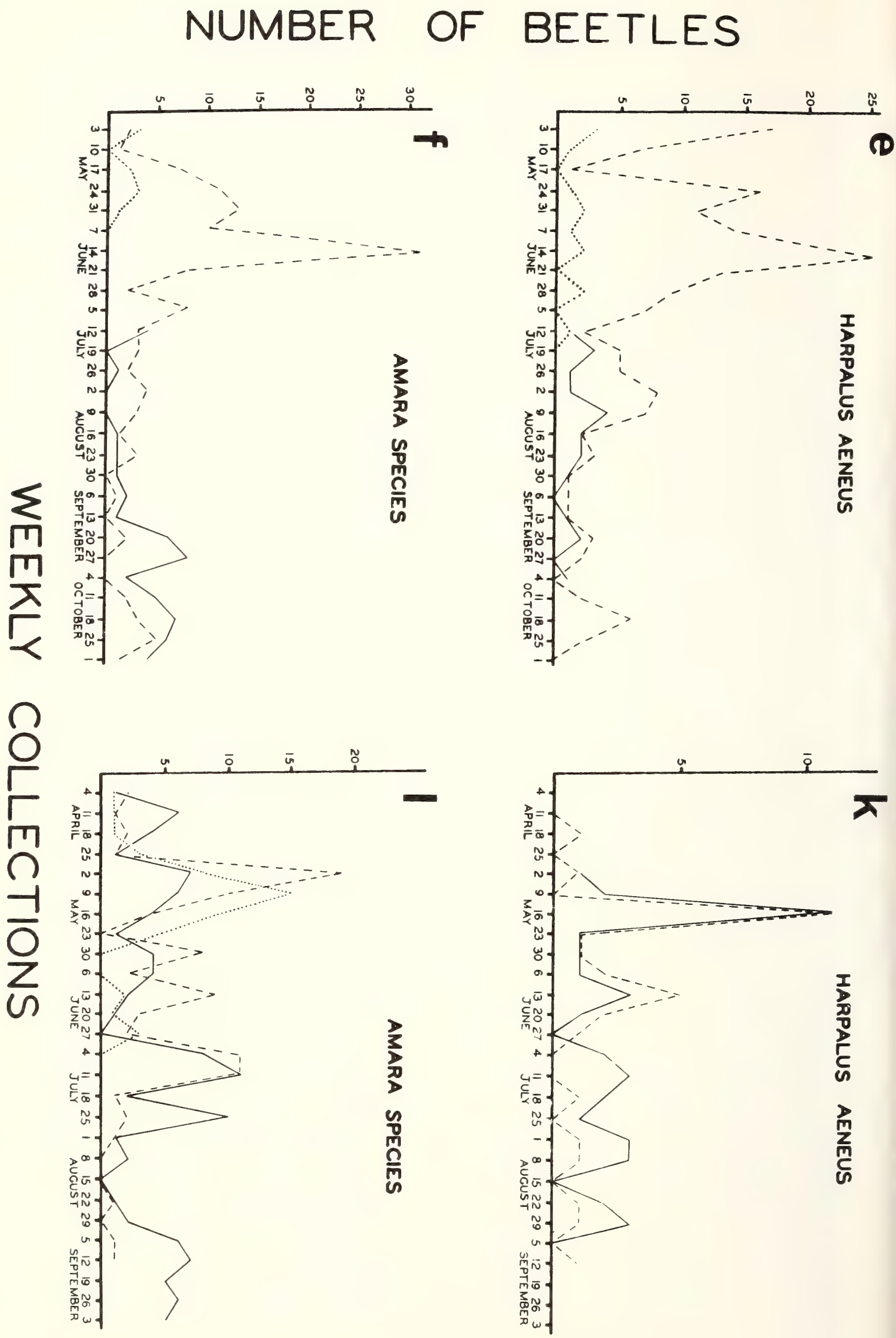
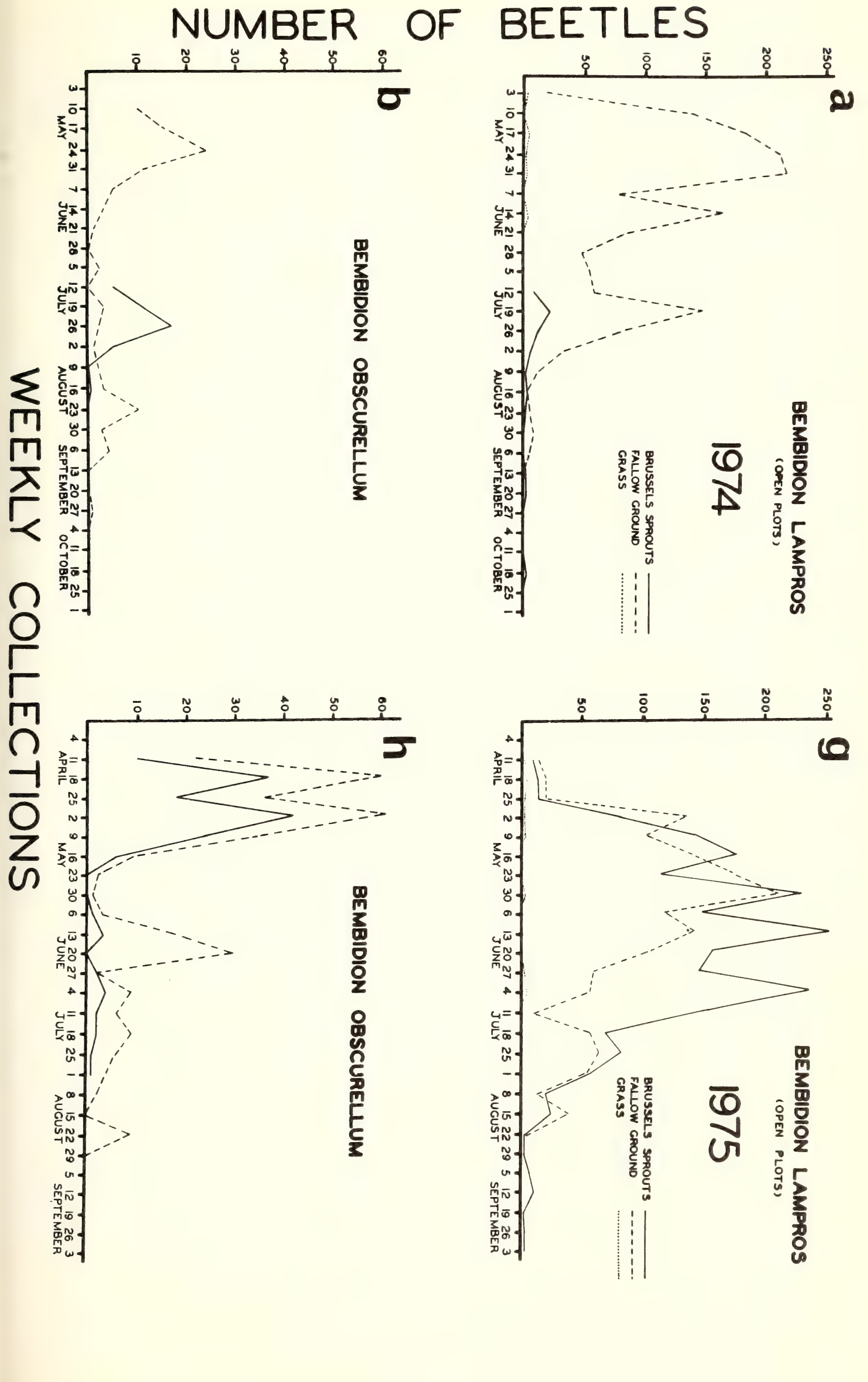
Fig. 1. Population curves for six carabid beetles on crop, fallow and grass plots, enclosed by barriers, at Abbotsford, B.C. in 1974 (a-f) and 1975 (g-1).

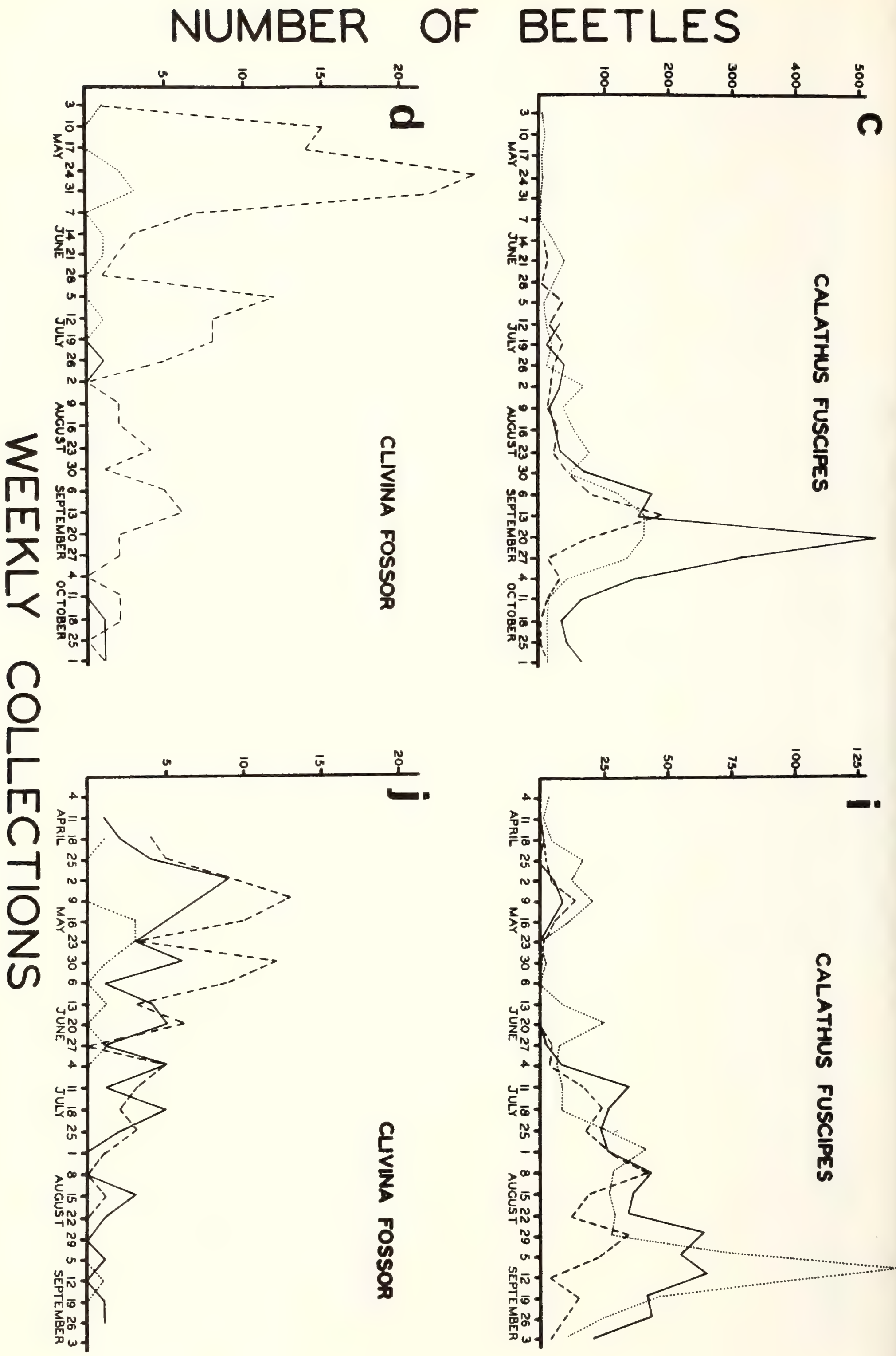
Fig. 2. Population curves for six carabid beetles on crop, fallow and grass plots, not enclosed by barriers, at Abbotsford, B.C. in 1974 (a-f) and 1975 (g-1).

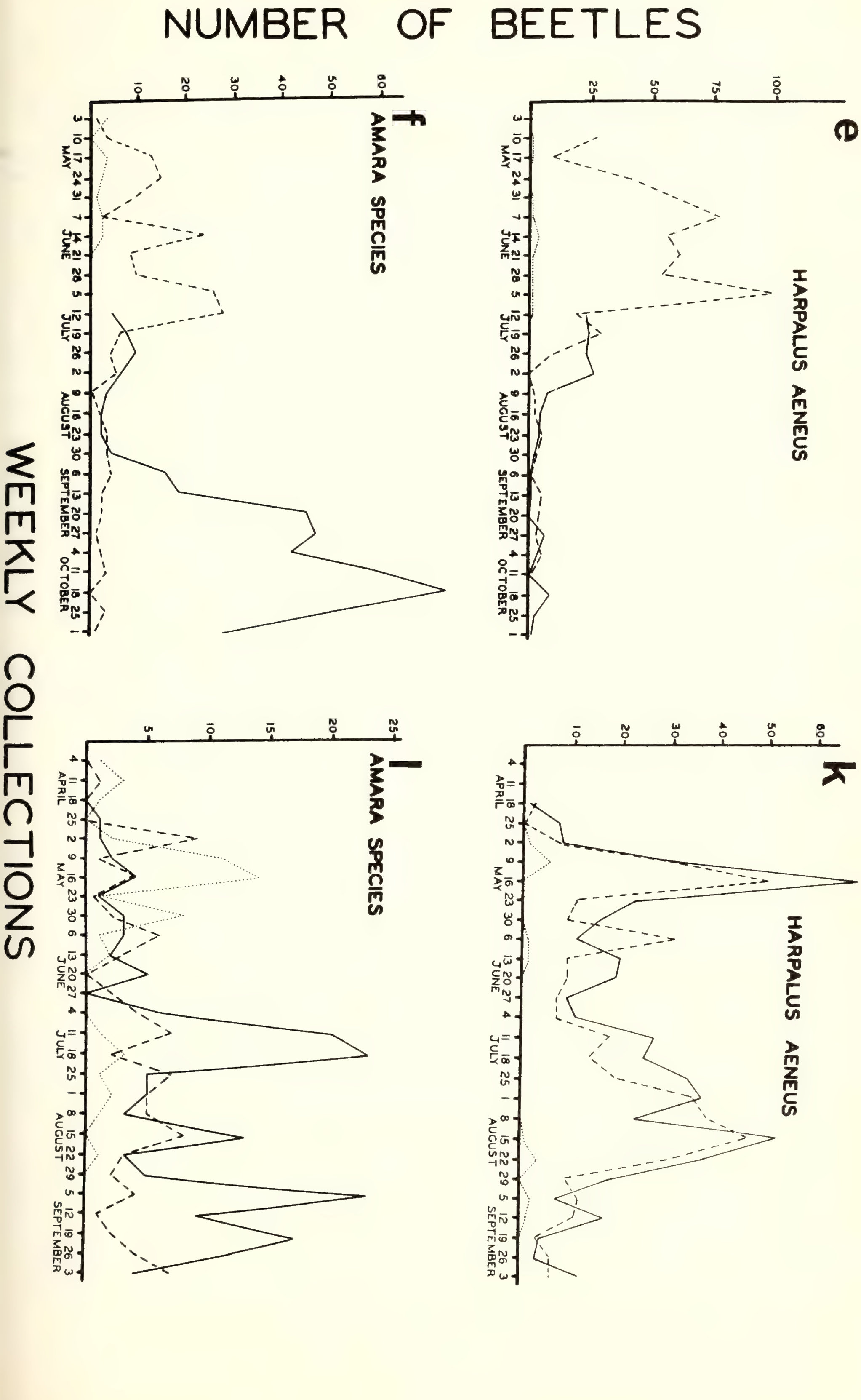

NUMBER OF BEETLES
WEEKLY COLLECTIONS
a
BEMBIDION LAMPROS
(BARRIER PLOTS)
1974
BRUSSELS SPROUTS
FALLOW GROUND
GRASS
b
BEMBIDION OBSCURELLUM
g
BEMBIDION LAMPROS
(BARRIER PLOTS)
1975
BRUSSELS SPROUTS
FALLOW GROUND
GRASS
h
BEMBIDION OBSCURELLUM


NUMBER OF BEETLES
WEEKLY COLLECTIONS
c
CALATHUS FUSCIPES
d
CLIVINA FOSSOR
i
CALATHUS FUSCIPES
j
CLIVINA FOSSOR


NUMBER OF BEETLES
WEEKLY COLLECTIONS
e
HARPALUS AENEUS
f
AMARA SPECIES
k
HARPALUS AENEUS
l
AMARA SPECIES


NUMBER OF BEETLES
WEEKLY COLLECTIONS
a
BEMBIDION LAMPROS
(OPEN PLOTS)
1974
BRUSSELS SPROUTS
FALLOW GROUND
GRASS
b
BEMBIDION OBSCURELLUM
g
BEMBIDION LAMPROS
(OPEN PLOTS)
1975
BRUSSELS SPROUTS
FALLOW GROUND
GRASS
h
BEMBIDION OBSCURELLUM


NUMBER OF BEETLES
WEEKLY COLLECTIONS
c
CALATHUS FUSCIPES
d
CLIVINA FOSSOR
i
CALATHUS FUSCIPES
j
CLIVINA FOSSOR
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
APRIL


NUMBER OF BEETLES
WEEKLY COLLECTIONS
e
HARPALUS AENEUS
f
AMARA SPECIES
k
HARPALUS AENEUS
l
AMARA SPECIES

References

Briggs, J. B. 1957. Some experiments on control of ground beetle damage to strawberry. 44th Rep. E. Malling Res. Sta. 1955-1956. 142-145.

Coaker, T. H. 1965. Further experiments on the effect of beetle predators on the numbers of cabbage root fly, **Erioischia brassicae** (Bouché), attacking brassica crops. Ann. appl. Biol. 56:7-20.

Coaker, T. H. and D. A. Williams. 1963. The importance of some Carabidae and Staphylinidae as predators of the cabbage root fly, **Erioischia brassicae** (Bouché). Ent. exp. et appl. 6:156-164.

Finlayson, D. G., C. J. Campbell and H. A. Roberts. 1975. Herbicides and insecticides: their compatibility and effects on weeds, insects and earthworms in the minicauliflower crop. Ann. appl. Biol. 79: 95-108.

Gibson, A and R. C. Treherne. 1916. The cabbage root maggot and its control in Canada with notes on the imported onion maggot and seed-corn maggot. Canada Dep. Agr. Entomol. Branch Bull 12. 58 pp.

Greenslade, P. J. M. 1964. Pitfall trapping as a method for studying populations of Carabidae (Coleoptera). J. Anim. Ecol. 33:301-310.

Hatch, M. H. 1953. The beetles of the Pacific northwest. Part I: Introduction and Adephaga. Univ. of Wash. Press, Seattle.

Hatch, M. H. 1957. The beetles of the Pacific northwest. Part II: Staphyliniformia. Univ. of Wash. Press, Seattle.

Tsinovskii, Ya. P. 1961. **Clivina fossor** L. a pest of corn in the environment of Latvian SSR. Tr. Inst. Biol. Akad. Navk. Latviisk. SSR 20: 163-164 (#15685 Biol. Abs. 42: 1237, 1963).

Wilkes, A. and G. Wishart. 1953. Studies on parasites of root maggots (**Hylemya** spp.; Diptera: Anthomyiidae) in the Netherlands in relation to their control in Canada. Tijdschr. PPziebt. 59: 185-188.

Wishart, G., J. F. Doane and G. E. Maybe. 1956. Notes on beetles as predators of eggs of **Hylemyia brassicae** (Bouché). Canadian Entomol. 88: 634-639.

Wright, D. W. 1956. Entomology report. Rep. Nat. Veg. Res. Sta. Wellesbourne (1955) 47.

Wright, D. W., R. D. Hughes, and J. Worrall. 1960. The effect of certain predators on the numbers of cabbage root fly (**Erioischia brassicae** (Bouché)) and on subsequent damage caused by the pest. Ann. appl. biol. 48: 756-763.

UNDERSTORY PLANTS AS INDICATORS OF GRAND FIR MORTALITY DUE TO THE FIR ENGRAVER[1]

By

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ABSTRACT

Mortality of grand fir trees, caused by the fir engraver, *Scolytus ventralis*, was monitored during 3 years on ten 0.1 acre (0.04 ha) circular plots in each of nine stands in northern Idaho. Understory vegetation was sampled on each plot on the basis of circular subplots of 0.03 acre (0.012 ha). Analyses showed four species to be strongly correlated with high and two with low tree mortality. The interaction between these groups of plant species provided a variable that increased as the proportion of high to low hazard plants increased. Various linear and nonlinear expressions were tested between the two plant groups and their interaction regressed against killed trees per acre. The plant group interaction term accounted for the most variation (r^2=0.914) and produced the lowest standard error of the estimate (1.55). The equation for this variable took the form Y=2.291 + 0.111ex, where X=plant group interaction. This equation provides an indication of the susceptibility of grand fir stands to mortality caused by the fir engraver.

Grand fir, *Abies grandis* (Dougl.) Lindl., is a major component of the grand fir - western larch - Douglas-fir type in the northwestern United States and southern British Columbia (Fowells 1965). In Idaho, this species comprises half (874 M acres) (349.6 M ha) of the total acreage occupied by the spruce-fir group of types (Wilson 1962).

Numerous insect species attack grand fir, but most of them cause little damage and are of relatively minor economic importance. The western balsam bark beetle, *Dryocetes confusus* Sw., and the fir engraver, *Scolytus ventralis* LeConte, are the principal bark beetle pests (Fowells 1965). Epidemic infestations of the fir engraver are sometimes severe, but relatively localized and may be correlated with epidemics of the Douglas-fir tussock moth, *Orygia pseudotsugata* (McD.) (Berryman 1973). As an example of their severity, Stevens (1971) reported that about 37,000 grand fir trees were killed in 1954 on 6,000 acres (4800 ha) of the Cibola National Forest in New Mexico.

Parasites and predators may help to control the fir engraver in some years (Massey 1966, Ashraf and Berryman 1970), but generally are considered ineffective in preventing outbreaks (Stevens 1971). Chemical control methods under forest conditions are considered by most workers to be limited because of the wide variation in the pattern of attack and injury to the host tree. Little or no benefit is gained by chemically destroying fir engraver broods in trees under mass attack, unless those broods in top-killed and "patch" attacked trees (having the potential to sustain or regenerate an epidemic) are also identified and destroyed (Keen 1952, Struble 1957, Stevens 1971).

Silvicultural methods probably offer the best possibility for minimizing losses. This approach requires cultural practices that remove trees predisposed to attack, and the maintenance of stand vigor and resistance through regulation of density and composition. Attainment of these objectives necessitates a stand hazard rating system that will help forest managers to assign treatment priorities. The system should be based on data easily obtained during the taking of standard timber inventories.

It has been demonstrated that, in the northern Rocky Mountains, the subordinate plant unions reflect differences in site characteristics (Daubenmire and Daubenmire 1968). Thus, it seemed likely that the presence or absence of certain understory plant species or species groups could indicate site conditions favorable or unfavorable to high mortality caused by the fir engraver. A plant species group as used here is a collection of plants with similar relationships to a specified variable.

The study was conducted in three experimental areas (replicates), each consisting of three study sites, established on lands of the

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Potlatch Corporation in northern Idaho. Two replicates (Gold Creek and Lost Creek) are located in *Abies grandis/Pachistima myrsinites* habitat types in Latah County and the third replicate (Jaype) is located in a *Thuja plicata/ Pachistima myrsinites* habitat type in Clearwater County. In each study grand fir comprises between 63% and 76% of the stems per acre of more than 3 inches dbh.

Ten circular plots each of 0.1 acre (0.04 ha) were systematically located with a random start within each of the nine study sites. Grand fir mortality attributable to the fir engraver was monitored in each plot for 3 years (1972-1974). The total mortality per acre caused by the fir engraver in each study site was then calculated.

Understory vegetation was sampled on each 0.1-acre plot during late summer of 1974, using 0.03-acre (0.012 ha) circular subplots with witnessed and staked plot centers. These vegetation plots were offset 18 feet from the 0.1-acre plot centers to avoid the disturbance resulting from frequent visits to the main plot centers. All perennial shrubs, forbs, and graminoids on each plot were recorded. An ocular estimate of percent cover with low and tall shrub species also was recorded for each plot.

Within any given study site, the subordinate plant complex was not influenced by topography. We calculated the frequency or percentage of the total number of understory vegetation plots occupied by each herbaceous and shrub species at each study site, and also the average percentage cover for each shrub species.

The frequencies or average percentage cover of about 50 plant species were evaluated by means of correlation matrices, using killed trees per acre during three years as one variable and, as the other, frequency of a herb or shrub species, or the average percentage cover of a shrub. We assumed that the composition of the subordinate plant complex and its relationship to the site would remain unchanged during the three years in the absence of outside disturbance and considering only perennial plant species. Based on this assumption, plant data collected at the end of the mortality period were used to indicate a relationship to mortality in stands where fir engraver populations were likely to be present. Those species showing direct or inverse correlation coefficients of 0.80 or more were subjectively accepted as indicating high or low mortality caused by the fir engraver. Six species were thus selected for further analyses.

Results

Four of the six plant species had frequencies that were directly correlated (group A), and two had frequencies that were inversely correlated (group B), with killed trees per acre during the three years (Table 1). Additional analysis showed a high degree of correlation between the frequency of a given plant species and the frequency of other species having a similar (direct or inverse) correlation. The frequency of each group was then calculated for each study site, based on the percentage of the total number of understory vegetation subplots within each study site in which any single member species of the plant group occurred.

The interaction between the frequencies of the two plant species groups produced a variable that increased with the proportion of group A or high hazard to group B or low hazard plants. This is expressed by:

$$PGI = fA/1 + fB$$

where:

PGI=plant group interaction
fA=frequency of occurrence of plant species in group A.
fB=frequency of occurrence of plant species in group B.

Table 1. Correlation coefficients for plant species correlated with grand fir trees killed per acre by the fir engraver during 3 years, in northern Idaho, 1974.

Plant species variable	Common name	Usual habitat1/	r
Carex deweyana Schw.	Dewey's sedge	Moist woodlands to forest openings	0.886
Arenaria macrophylla Hook.	Sandwort	Moist to dry, shaded to open woods	0.812
Satureja douglasii (Benth.) Breq.	Yerba buena	Coniferous woods	0.825
Holodiscus discolor (Pursh) Maxim.	Oceanspray	Open dry to moist woods	0.946
Clintonia uniflora (Schult.) Kunth.	Blue-bead lily	Moist coniferous woods	-0.822
Chimaphila umbellata (L.) Bart.	Pipsissewa	Under conifers in woods	-0.820

1/Scientific name, common name and usual habitat from Hitchcock and Cronquist 1973.

To develop a mathematical expression that would relate understory vegetation variables to trees killed per acre by the fir engraver during the three years, we tested various linear and non-linear expressions of plant species groups A and B, and plant group interaction, regressed against trees killed per acre. The best mathematical equations for these variables took the following form:

$$Y=1.922 - 0.809X_1^2 + 1.713X_1^4 \qquad (1)$$

$$Y=15.045 - 0.136X_2 \qquad (2)$$

$$Y=2.291 + 0.111e^{X_3} \qquad (3)$$

where:

Y=trees killed per acre by the fir engraver during 3 years (KTA)

X_1 =frequency of occurrence of plant species in group A

X_2=frequency of occurrence of plant species in group B

X_3 =plant species group interaction $(X_1 /1 + X_2)$

The correlation coefficients for equations 1—3 are 0.954, -0.917 and 0.956, and their standard error of the estimates are 1.634, 1.765, and 1.550 respectively. The variable that accounted for the most variation and also produced the lowest standard error of the estimate was plant group interaction (equation 3) which accounted for 92% of the variation in KTA, and is significant at an α level of .01.

Discussion

It is noteworthy that the plant species in group A are considered seral and those in group B are considered climax species when the subordinate plant union is *Pachistima myrsinites* (Daubenmire and Daubenmire 1968). Thus, the presence of group A species indicates a site presumably less conducive, and the presence of group B species indicates a site more conducive, to the maintenance of favorable moisture conditions and vigor of grand fir.

The value of the relationship reported here is its use as a means of ranking sites supporting grand fir according to their potential susceptibility. The level of mortality is dependent upon stand variables, upon the intensity of stress imposed on the site by adverse abiotic factors, and upon the population levels of the fir engraver. Other predisposing factors include the presence of root disease (Partridge and Miller 1972), and the reduced ability of trees to produce traumatic resin canals (Berryman 1969, Berryman and Ashraf 1970).

In practice the subordinate plant union would be sampled at each plot center during the regular timber inventory, using 0.03-acre circular plots, and recording the presence of each plant species group. At each plot, a plant species group would be recorded as present if any of the member species were present. The plant group interaction term (PGI) would be calculated and used as the independent variable in equation 3 to indicate the susceptibility of the stand of grand fir to mortality caused by fir engraver.

Table 2. Correlation matrix between the frequencies of plant species in two groups, northern Idaho, 1974.

y/x	1	2	3	4	5	6
1	1.000					
2	0.796	1.000				
3	0.898	0.767	1.000			
4	0.887	0.738	0.905	1.000		
5	-0.783	-0.702	-0.701	-0.833	1.000	
6	-0.912	-0.775	-0.973	-0.885	0.613	1.000

Plant Group A

1, *Holodiscus discolor* (Pursh) Maxim.
2. *Carex deweyana* Schw.
3. *Arenaria macrophylla* Hook.
4. *Satureja douglasii* (Benth.) Briq.

Plant Group B

5. *Clintonia uniflora* (Schult.) Kunth.
6. *Chimaphila umbellata* (L.) Bart.

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The authors acknowledge the assistance of Frederic D. Johnson, Douglass M. Henderson, and James E. Jewell, Professor, Assistant Professor, and Graduate Assistant, University of Idaho, respectively, in plant species identification.

Literature Cited

1. Ashraf, M. and A. A. Berryman. 1970. Biology of **Sulphuretylenchus elongatus** (Nematoda: Sphaerulariidae), and its effect on its host, **Scolytus ventralis** (Coleoptera: Scolytidae). Can. Entomol. 102: 197-213.
2. Berryman, A. A. 1969. Response of **Abies grandis** to attack by **Scolytus ventralis** (Coleoptera: Scolytidae). Can. Entomol. 101: 1033-1041.
3. ______________1973. Population dynamics of the fir engraver, **Scolytus ventralis** (Coleoptera: Scolytidae), I. Analysis of population behaviour and survival from 1964 to 1971. Can. Entomol. 105: 1465-1488.
4. ______________and M. Ashraf. 1970. Effects of **Abies grandis** resin on the attack behaviour and brood survival of **Scolytus ventralis** (Coleoptera: Scolytidae). Can. Entomo. 102: 1229-1236.
5. Daubenmire, R. and J. B. Daubenmire. 1968. Forest vegetation of eastern Washington and northern Idaho. Wash. State Univ., Agr. Exp. Sta. Tech. Bull. 60, 104 pp.
6. Fowells, H. A. 1965. (ed.). Silvics of forest trees of the United States. U. S. Dept. Agr., Agr. Handbk. 271, 762 pp.
7. Hitchcock, C. L. and A. Cronquist. 1973. Flora of the Pacific Northwest. U. of Wash. Press., 730 pp.
8. Keen, F. P. 1952. Insect enemies of western forests. U.S. Dept. Agr., Misc. Publ. 273, 280 pp.
9. Massey, C. L. 1966. The influence of nematode parasites and associates on bark beetles in the United States, Bull. Entomol. Soc. Amer. 12: 384-386.
10. Partridge, A. D. and D. L. Miller. 1972. Bark beetles and root rots related in Idaho conifers. Plant Disease Reptr. 56: 498-500.
11. Stevens, R. E. 1971. Fir engraver. U. S. Dept. Agr., Forest Service, Forest Pest Leafl. 13, 7 pp.
12. Struble, G. R. 1957. The fir engraver, a serious enemy of western true firs. U.S. Dept. Agr., Prod. Res. Rept. 11, 18 pp.
13. Wilson, A. K. 1962. Timber resources of Idaho. U.S. Dept. Agr., Forest Service, Intermt. Forest and Range Exp. Sta., Forest Survey Release 3, 42 pp.

CONE AND SEED INSECTS OF SUBALPINE FIR DURING A YEAR OF LOW CONE PRODUCTION IN NORTHERN IDAHO[1]

By

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ABSTRACT

Cone and seed insects destroyed 29 percent of the seed crop of subalpine fir (**Abies lasiocarpa**) in the Freezeout Mountain area of northern Idaho in 1972 during a year of low cone production. Larvae of a coneworm, **Dioryctria abietivorella** destroyed 12 percent of the seed crop, accounting for 42 percent of the total insect damage. A newly discovered midge pest, a species of **Dasineura**, destroyed 11 percent of the seed crop, amounting to 40 percent of the total insect damage. The dipterans, **Hylemya abietis**, **Earoymia** sp., and **Asynapta keeni**, and the chalcid wasp, **Megastigmus lasiocarpae**, together destroyed 4 percent of the seed crop. Unknown causes accounted for 1.5 percent of the total seed destruction. X-ray was used to estimate seed lost to **M. lasiocarpae** and **Dasineura** sp. Regression equations are given relating cone length (mm), and the seeds on the axial surface, to total seeds. Sound and damaged seeds on the axial surface were highly correlated with the totals of sound and damaged seeds, respectively, in the cone.

INTRODUCTION

Insects inhabiting cones and seeds of subalpine fir, *Abies lasiocarpa* (Hook.) Nutt., have received little attention. Keen (1958) listed five species of insects that cause damage to subalpine fir cones: the fir coneworm, *Dioryctria abietella* (Denis and Schiffermueller) (= *D. abietivorella (Grote)*); a cone maggot, *Earomyia aquilonia* McAlpine; two species of seed chalcids in the genus *Megastigmus;* and a cone midge, *Asynapta keeni* (Foote). Hedlin (1974) states that *E. aquilonia* destroys most of the seeds in infested cones in British Columbia, and that the subalpine-fir chalcid, *Megastigmus lasiocarpae* Crosby, is not a serious pest. He constructed a key to the insects damaging cones in British Columbia. Moyer and Parker (1973), and Kulhavy, et al. (1975) presented a list of insects reared from these cones in Utah and Idaho. Kulhavy (1974) also constructed keys to the damage and to the insect pests of subalpine fir cones in Idaho.

Several methods are available to evaluate the damage within a cone and the impact on the seed crop. Cones can be halved longitudinally and counts made of insect-damaged, aborted, sound and the total seeds on the exposed axial surface (Winjum and Johnson 1960, McLemore 1961, and Bramlett and Hutchinson 1964). Seed-infesting insects may be detected by x-ray and dissections (Speers 1968, Fedde 1973). This paper reports on damage by cone and seed insects of subalpine fir in a year of very low cone production in northern Idaho, and on the reliability of estimating the damaged, sound, and the total numbers of seeds in cones.

METHODS

Subalpine fir cones were collected from early July through early September, 1972 from a 1.0 x 0.3 km. area in the Freezeout Mountain region of Shoshone County, Idaho. The collection area, primarily an *Abies lasiocarpa/ Xerophyllum tenax* habitat type (Daubenmire and Daubenmire 1968), has a slope of less than 10 percent to the southwest with an average elevation of 1800 m. From each of 15 cone bearing trees in the study area, 15 to 20 cones were collected for insect rearing and damage evaluation. These cones represented about 15 to 20 percent of the production in the area. The average height of the sampled trees was 9.3 m (range 3.1 to 13.7 m). The ages, taken at 1.3m height, averaged 27 years (range 20 to 40 years) and diameters averaged 20.0 cm (range 4.5 to 34.8 cm). Cones collected were placed either in one-gallon, single-light-source rearing cartons at 24°C, or dissected for insect damage. In the former case, the emerged adults were identified by specialists and included in a checklist (Kulhavy, et al. 1975), and in a key to damage (Kulhavy 1974).

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[3]An r^2 of 0.92 was obtained from a regression of seeds from one-half of a cone to total seeds within a cone.

From the 250 cone sample, 72 were completely disected within two weeks after collection for insect damage and seed estimation. These cones were cut in half lengthwise using a modified cone-knife cutter, and the numbers of insect-damaged seeds were counted on the exposed axial surface. Seeds were then hand extracted from one-half of each cone[3] (the half selected at random by the toss of a coin), counted and the seedwings removed. The seeds were then placed in plastic petri dishes and x-rayed for seed-infesting insects. The radiographs were made in Faxitron® Model 804 self-contained X-ray system at 15 kVP for 8 to 10 seconds using Polaroid® Type 52 Land film. The film was then developed for 10 to 15 seconds and coated with Polaroid print coater. The number of seed-infesting insects was counted and added to the damage caused by other insects. This value was regressed against the observed axial damage to estimate total insect damage.

The cone length (mm), width (mm), and axial seed count were regressed against the total number of seeds within one-half of a cone to obtain an estimate of the sound and total number of seeds within a cone. Observations on life history and behavior of the various species also were recorded.

RESULTS

Dioryctria abietivorella (Grote), fir coneworm

Larvae of this pyralid infested 20 percent of the examined cones and destroyed 45.7 percent of the seeds in the infested cones. It was the most destructive of all species, and caused 41.6 percent of the total insect damage, destroying 12.0 percent of the seed crop. Damage by *D. abietivorella* has been described by Keen (1958) and their feeding in subalpine fir cones is similar to that of related species in other trees species. The larvae often bore from one cone to another and through previously infested cones, leaving large masses of granular frass on the exterior of cones held together by webbing. Damaged cones turn brown and brittle by early August.

Larvae of *D. abietivorella* are behaviorally distinct from other lepidopteran pests of cones. When exposed, a mature larva immediately begins sealing its tunnel by spinning silk across the opeing, adding frass pellets to the lattice, then more silk. The behavior observed was similar to that seen in construction of pupal cells although the latter are lined with additional silk. A new species of parasitic Diptera in the genus *Lixophaga* (Tachinidae) was reared by us from larvae of *D. abielivorella.* The impact of this parasite is not known.

Dasineura sp., seed midge

Estimates of damage by the newly-discovered cecidomyiid pest of subalpine fir seeds were obtained from radiographs and seed dissections because the larvae feed internally in the seeds or underneath the seed coat. They destroyed 11.4 percent of the seed crop and accounted for 39.2 percent of the total insect damage. Mature larvae of this species are readily distinguished on radiographs from larvae of the seed chalcid, *Megastigmus lasiocarpae.* Late instar *M. lasiocarpae* larvae are distinclty "C" shaped and tapered at both ends, whereas larvae of *Dasineura* are straight or curved in the seeds, but not tapered.

This species overwinters as mature larvae but no pupae or adults were recovered. About 10 percent of the larvae were parasitized by a small, black, braconid wasp.

Asynapta keeni (Foote)

The larvae of this cecidomyiid were more abundant (700) then those of any other species. However, they accounted for only 1.2 percent of the total insect damage and destroyed 0.4 percent of the seed crop by resin exudation. The life cycle of the species in cones of subalpine fir is the same as it is in cones of grand fir, *Abies grandis* (Douglas) Lindley, (Kulhavy 1974). Adults emerge in late August or the following spring.

Hylemya abietis (Huckett)

One larva of this anthomyiid infested one subalpine fir cone and destroyed 32 seeds. This amounted to one percent of the insect-caused loss, or 0.3 percent of the seed crop. Larvae when removed from cones collected later became sluggish and constricted. They overwinter in puparia in the soil and adults emerge the following spring.

Earoymia sp.

Larvae of this lonchaeid caused 3.9 percent of the insect damage and destroyed 1.3 percent of the total seed crop in 1972. Seeds mined by the larvae become flat, resinous and dark brown. Only a very small amount of fine frass is produced. After the mature larvae leave a cone they move frantically until they find a suitable pupation site in the litter or soil. The larvae travel by three methods: (1) they wiggle the entire body, causing a rolling, twisting motion; (2) they alternately constrict and lengthen the body segments, resulting in a forward motion; and (3) they grasp fleshy areas near the posterior spiracles with one or both mouthhooks, which constricts the body into a "C" shape with the midbody segments flattened dorso-ventrally. When the mouthhooks are released, the larva is propelled for a distance of 8 to 15 cm. This snapping motion was stimulated in the laboratory and observed in the field, and has been reported previously for *E. aquilonia* by R. W. Reid as cited by McAlpine (1956).

TABLE 1. Summary of regression analyses for predicting total, filled, and damaged seeds in subalpine fir cones, northern Idaho, 1972 (n=72).

Dependent[1] Variables	Independent Variables	Intercept	Regression Coefficient	Standard error of estimate ($s_{y.x}$)	Coefficient of Determination (r^2)
Y_1	Length (mm.)	-50.4	2.09	19.6	.6055**
Y_1	Width (mm.)	-82.7	6.86	25.0	.3583**
Y_1	Length, Width	-62.2	1.96, 01.7	19.7	.6073**
Y_1	Axial seeds (Total)	-21.6	4.88	23.9	.4120**
Y_2	Axial sound seeds	14.0	3.47	28.0	.4668**
Y_3	Axial damaged seeds	9.2	2.55	15.5	.6777**

** Significantly different from zero at a=.01

1 Y_1=Total seed in one-half of a cone; Y2=total sound seeds in one-half of a cone; Y_3=total damaged seeds in one-half of a cone.

Megastigmus lasiocarpae Crosby

Larvae of this torymid destroyed 2.2 percent of the seed crop, which has 7.4 percent of the insect-caused seed loss. Damage by this seed-infesting chalcid was estimated from radiographs and seed dissections. Our observations agree with those of Keen (1958) who suggested that the species has a one year life cycle snychronized with cone development. The eggs are deposited in the seeds early in cone devlopment and the larvae feed singly. Only one larva develops if more than one egg is deposited within a seed. Overwintering occurs as mature larvae or pupae, and adults emerge the following spring. An undetermined portion of the population entered extended diapause in 1972 and emerged in 1974.

Unknown causes

These accounted for 1.5 percent of the total seed destruction.

Estimation of Seed Production and Damage

The number of seeds within subalpine fir cones can be reliably estimated (r^2=.6055, a=.01) from the cone length (Table 1). Neither cone width, nor the inclusion of both cone length and width improved the fit. Similarly, expressing the independent variables in logarithms, or fitting a second degree polynominal failed to significantly increase the fit.

The number of damaged seeds/cone also can be reliably estimated (r^2=.6777, a=.01) from counts of damaged seeds on an axial section (Table 1). However, the axial slice technique did not provide as good an estimate of the total number of seeds/cone (r^2=.4120), or the number of sound seeds/cone (r^2=.4668). Means and standard deviations for all variables are shown in Table 2.

DISCUSSION

Every cone dissected from the Freezeout Mountain area had at least one seed destroyed by insects. Insects destroyed 29.1 percent of the total seed crop during a year of very poor cone reproduction. This loss is magnified by the high percentage of aborted seeds, the naturally low viability of subalpine fir seeds (USDA

TABLE 2. Means and standard deviations for all variables for subalpine fir cones, northern Idaho, 1972.

Variable	Mean	Standard Deviation
Length (mm)	73.7	11.5
Width (mm)	28.7	2.7
Axial seeds (Total)	27.8	4.1
Axial sound seeds	7.1	7.7
Axial damaged seeds	9.1	8.7
Total sound seeds	37.2	38.0
Total damaged seeds	32.6	27.1
Total seeds	114.2	31.0

1974) and the cyclic nature of cone crops. Desiccation of the seeds adversely affects survival and seedling establishment during the first season of growth. In the Freezeout Mountain area, the establishment of seedlings was further hindered by the light intensity (USDA 1965) which exceeded 50 percent full sunlight. The similarity and proximity of the insect pests of grand fir cones (Kulhavy 1974, Kulhavy et al., 1975) indicate that the infestations probably were from overwintering or emigrating insects. The most destructive insect species, the coneworm, is an ubiquitous pest of cones and was also the most destructive pest of grand fir cones (Kulhavy 1974, Kulhavy and Schenk in press).

To obtain a reliable estimate of loss to cone and seed insects, damage by the insects feeding internally must be taken into account. Thus, a portion of the seeds should be examined by radiography or dissected to estimate the damage. Although reliable estimates were obtained of the total damage from the number of damaged seeds on the axial surface, and of total seeds per cone from the cone length, Kulhavy, (1974) has shown that there is high variability over the range of grand fir. Similar variability in subalpine fir is likely. Thus, the equation for predicting seeds in subalpine fir cones should be tested at different levels of cone production and insect populations and over a broader geographic range before applying it indiscriminately.

The loss of seeds to insects, coupled with the cyclic nature of cone crops and the generally poor germination of subalpine fir, are factors that should be considered before planning a timber harvest where natural regeneration is desired.

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LITERATURE CITED

Bramlett, D. L., and J. G. Hutchinson. 1964. Estimating sound seed per cone in shortleaf pine. U.S. Dept. Agr. Forest Serv. Res. Note SE-18. 2 pp.

Daubenmire, R., and J. B. Daubenmire. 1968. Forest vegetation of eastern Washington and northern Idaho. Wash. State Univ. Agr. Exp. Sta. Tech. Bull. No. 60. 104 pp.

Fedde, G. F. 1973. Impact of the balsam woolly aphid (Homoptera: Phylloxeridae) on cones and seed produced by infested Fraser fir. Can. Entomol. 105:673-680.

Hedlin, A. F. 1974. Cone and seed insects of British Columbia. Pacific Forest Res. Cen., Victoria, Brit. Col. 63 pp.

Keen, F. P. 1958. Cone and seed insects of western forest trees. U.S. Dept. Agr. Misc. Bull. No. 1169. 168 pp.

Kulhavy, D. L. 1974. Cone and seed insects of grand and subalpine firs in northern Idaho. College of Forestry, Wildlife and Range Sciences, M.S. thesis, University of Idaho. 79 pp.

Kulhavy, D. L, J. W. Dale, and J. A. Schenk. 1975. A checklist of the cone and seed insects of Idaho. Forest, Wildlife and Range Experiment Station, Univ. of Idaho, Info. Ser. No. 6. 28 pp.

Kulhavy, D. L. and J. A. Schenk. 1976. An evaluation of damage by cone and seed insects of grand fir in northern Idaho. Univ. of Idaho, Dept. of Entomol. 50th Anniversary Pub. (in press).

McAlpine, J. F. 1956. Cone-infesting Lonchaeids of the genus **Earomyia** Zett, with descriptions of five new species from western North America (Diptera: Lonchaeidae). Can. Entomol. 88:178-196.

McLemore, B. F. 1961. Estimating pine seed yields. U.S. Dept. Agr. Forest Serv. SE Exp. Sta. Rep. No. 134. 2 pp.

Moyer, M. M., and D. L. Parker. 1973. A revised list of seed and cone insects collected from native conifers in the Intermountain Region. Branch of Forest Insect and Disease Prevention and Control. U.S. Dept. Agr. Forest Serv., Ogden, Utah. 15 pp.

Speers, C. F. 1968. Insect infestation distorts Fraser Fir seed tests. U.S. Dept. Agr. Forest Serv. Tree Planters' Notes 18:19-21.

U.S. Dept. Agr. 1965. Silvics of forest trees of the United States. U.S. Dept. Agr. Forest Serv. Handbook No. 271. 762 pp.

U.S. Dept. Agr. 1974. Seeds of woody plants in the United States. U.S. Dept. Agr. Handbook No. 450. 883 pp.

Winjum, J. K., and N. E. Johnson. 1960. A modified knife-cone cutter for Douglas fir seed studies. J. Forest. 58:487-488.

THE STYLETS OF THE LARGE MILKWEED BUG, *ONCOPELTUS FASCIATUS* (HEMIPTERA: LYGAEIDAE , AND THEIR INNERVATION[1]

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ABSTRACT

Sections of the stylets of the large milkweed bug were examined in the electron microscope. They differ from those of 29 spp. of Homoptera studied earlier, in having: flanges on the maxillary stylets that engage grooves in the mandibular stylets; three large and three small dendrites in the central duct within the mandibular stylets; and a large salivary canal.

INTRODUCTION

The large milkweed bug, *Oncopeltus fasciatus* (Dallas), is a widely used research animal since it is reasonably large and can be reared easily in the laboratory throughout the year. Its widespread usage prompted a review of published information on its morphology, physiology and behavior (Feir 1974). No information on the structure of its stylets is included in this review, nor are there other reports on their fine structure. The present paper describes the stylets of this bug and compares them with the stylets of some Hemiptera (Suborder Homoptera) studied previously.

MATERIALS AND METHODS

The large milkweed bugs were from colonies maintained in the laboratory at the University of British Columbia.

The stylets were dissected from the bugs and immediately fixed simultaneously for 1 hr. on ice in 2% osmium tetroxide and 4% glutaraldehyde, both in 0.1 M cacodylate buffer, washed in 0.1 M cacodylate buffer (pH 7), post-fixed in 2% osmium tetroxide in the same buffer for ½ hr, dehydrated in ethanol, and embedded in Epon 812 by the method of Luft (1961). The sections were cut with glass knives on a Reichert Om U2 ultramicrotome, mounted on grids with carbon-collodion supporting films and stained with uranyl acetate and lead citrate. They were examined with Philips 200 or 300 electron microscopes.

RESULTS AND DISCUSSION

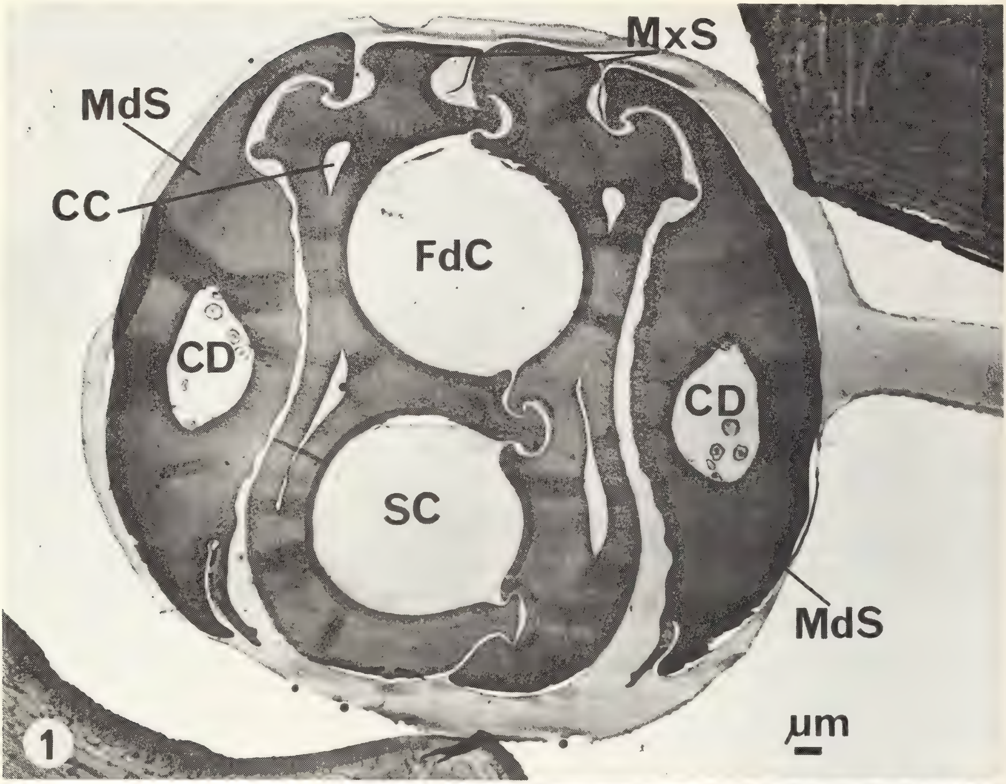
The piercing-sucking organs of the large milkweed bug consist of a pair each of mandibular and maxillary stylets. Each stylet has an enlarged base within the head capsule and an elongated shaft mostly outside the head. Except at the bases, the mandibular stylets envelop the maxillary stylets closely, so that in a cross section of the stylet bundle (Fig. 1), the mandibular stylets are on the outside and the maxillary stylets are on the inside. Except at their bases, the maxillary stylets are interlocked by a system of ridges and grooves. On the inner surface of each maxillary stylet there are two wide concavities which together form the food and the salivary canals. The food canal is anterior to and only slightly larger than the salivary canal. The bug injects saliva into the milkweed seed by way of the salivary canal and sucks the food material into the gut by way of the food canal.

More specific morphological details are as follows:

The maxillary stylets are only slightly longer (5%) than the mandibular stylets. The length of the stylets, including the base is about 6 mm. The tip of each mandibular stylet has a series of transverse, barb-like teeth across its outer face. A cross section of the whole stylet bundle, about midway in the shafts (Fig. 1) shows the interlocked maxillary stylets with the food and salivary canals between their apposed inner surfaces. The stylet bundle is approximately 26 micrometers in diameter, the food canal 9 micrometers in diameter and the salivary canal 8 micrometers in diameter. The salivary canal is thus only slightly smaller than the food canal. The mechanism that interlocks the maxillary stylets consists of three grooves in the right maxillary stylet and two grooves and three flanged ridges in the left. The maxillary stylets are not bilaterally symmetrical. There is a ridge with two flanges at the anterior margin of the outer surface of each maxillary stylet which fits into a groove on the inner surface of each mandibular stylet. This produces a compactly interlocked stylet bundle but the interlocking mechanism is such that independent movement upon one another is possible for each of the four stylets. The body of each maxillary stylet also contains a narrow central cavity which often appears in sections as two cavities because of the apposition of parts of its walls.

Each mandibular stylet contains a central duct running from the base to near the tip. The

[1]Contribution No. 390, Research Station, 6660 N. W. Marine Drive, Vancouver, British Columbia, V6T 1X2.



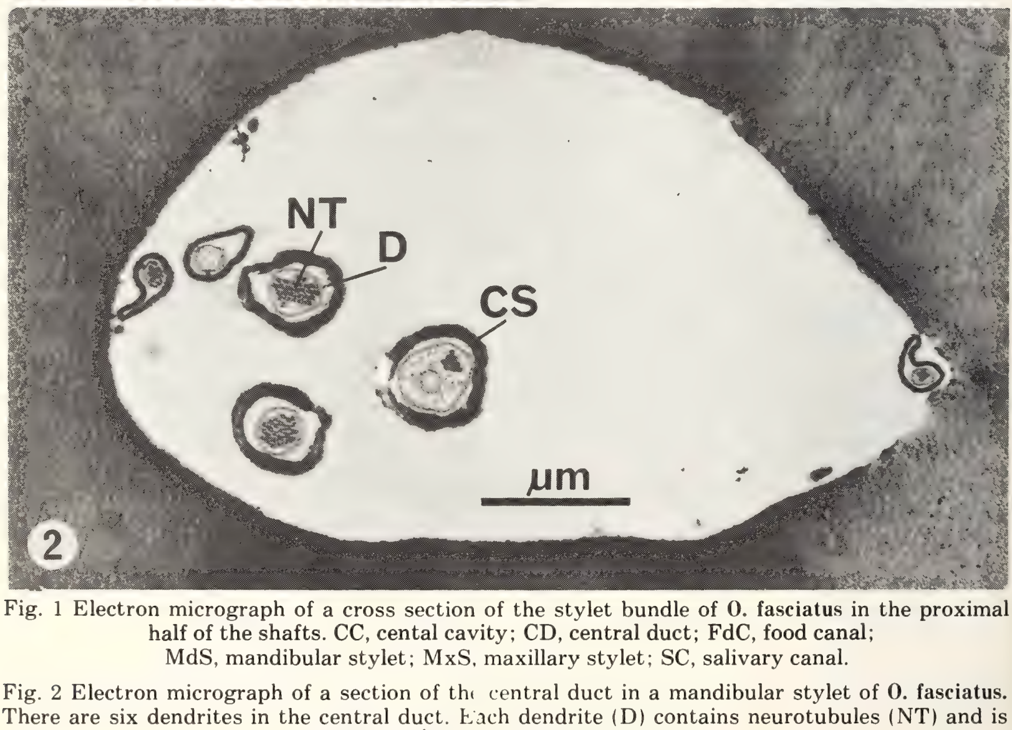


Fig. 1 Electron micrograph of a cross section of the stylet bundle of O. fasciatus in the proximal half of the shafts. CC, cental cavity; CD, central duct; FdC, food canal; MdS, mandibular stylet; MxS, maxillary stylet; SC, salivary canal.

Fig. 2 Electron micrograph of a section of the central duct in a mandibular stylet of O. fasciatus. There are six dendrites in the central duct. Each dendrite (D) contains neurotubules (NT) and is surrounded by a cuticular sheath (CS).

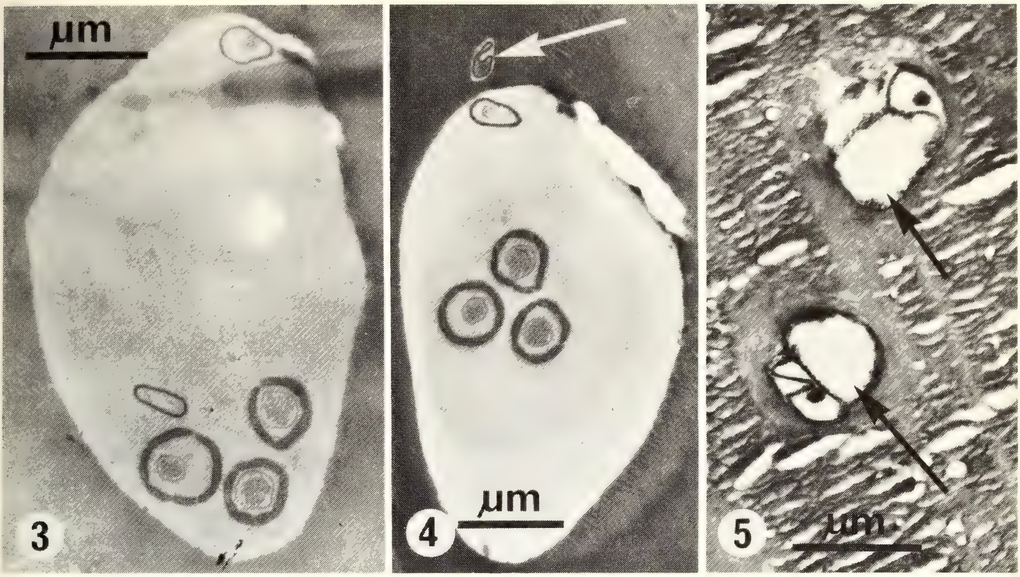


Fig. 3-5 Electron micrographs of sections of the central duct in the mandibular stylets of O. fasciatus. 3. midway, about three mm from the tip, showing five dendrites in the duct 4. about two mm from the tip, showing four dendrites in the duct and one (arrow) in the wall of the stylet. 5. at the stylet tip, after the central duct has bifurcated. The two branches of the central duct are indicated by arrows.

central duct is approximately 2 by 6 micrometers and contains six dendrites. All the dendrites were traced from the base of the mandibular stylet to midway along the stylet bundle. The dendrites are of two types: three large dendrites which are usually near the centre of the duct and away from the walls; and three smaller dendrites usually placed peripherally and close to the wall (Fig. 2). About midway along the stylet bundle one of the small, peripheral dendrites leaves the central duct and proceeds to the outside of the stylet and a receptor site, leaving five dendrites in the central duct (Fig. 3). About 1 mm closer to the tip, another of the small, peripheral dendrites leaves the duct (Fig. 4), leaving only 4 dendrites in the duct (Fig. 4). The last small peripheral dendrite leaves the duct. about 1 mm further distad, leaving only the three large dendrites in the duct. Close to the tip of the stylet, the central duct bifurcates (Fig. 5); one branch contains two dendrites, the other branch contains one.

The stylets of the large milkweed bug differ in some respects from those of the Hemiptera (Suborder Homoptera) previously studied by me (Forbes 1969 & 1972, Forbes & Mullick 1970, Forbes & Raine 1973, Chan & Forbes 1975). The salivary canal of the large milkweed bug is almost as large as the food canal, presumably because large amounts of saliva are needed to soften the somewhat dry food before it can be sucked up the food canal; aphids, the six-spotted leafhopper, the greenhouse whitefly, the pear psylla, and the balsam woolly aphid all have a salivary canal which is much smaller than the food canal. These all suck liquid plant sap, so that presumably less saliva is required when they feed. The body of each maxillary stylet of the large milkweed bug contains a large, narrow central cavity, which is apparently empty; the maxillary stylets of the six-spotted leafhopper also have cavities but these contain dendrites. There are ridges and grooves that interlock the maxillary with the mandibular stylets of the large milkweed bug; no such interlocking mechanism occurs in any of the homopterous insects mentioned. The central duct in the mandibular stylets of the large milkweed bug contain six dentrites, three of which are smaller and go to receptor sites proximad to the tip of the stylet and three of which are larger and reach the stylet tip; all of more than 25 species of aphids examined have mandibular stylets with two similar dendrites running to their tips (Forbes 1969 & unpublished, Chan & Forbes 1975). The greenhouse whitefly and the pear psylla also have two dentrites running to the stylet tips but the balsam woolly aphid has three. The six-spotted leafhopper's mandubular stylets have three dendrites which run to their tips or very close to them.

The structure and function of the stylets of other Hemiptera and the probable significance of the nerves in the stylets have been discussed in my earlier papers already cited.

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References

Chan, C-K, and A. R. Forbes. 1975. Life-cycle of a spiral gall aphid, **Pemphigus spirothecae** (Homoptera: Aphididae) on poplar in British Columbia. J. Ent. Soc. Brit. Columbia. 72:26-30.

Feir, D. 1974, **Oncopeltus fasciatus:** a research animal. Ann., Rev. Ent. 19:81-96.

Forbes, A. R. 1969. The stylets of the green peach aphid, **Myzus persicae** (Homoptera: Aphididae). Can. Ent. 101:31-41.

__________. 1972. Innervation of the stylets of the pear psylla, **Psylla pyricola** (Homoptera: Psyllidae), and the greenhouse whitefly, **Trialeurodes vaporariorum** (Homoptera: Aleyrodidae). J. Ent. Soc. Brit. Columbia. 69:27-30.

Forbes, A. R., and D. B. Mullick. 1970. The stylets of the balsam woolly aphid, **Adelges piceae** (Homoptera: Adelgidae). Can. Ent. 102:1074-1082.

Forbes, A. R., and J. Raine. 1973. The stylets of the six-spotted leafhopper, **Macrosteles fascifrons** (Homoptera: Cicadellidae). Can. Ent. 105:559-567.

Luft, J. H. 1961. Improvements in epoxy resin embedding methods. J. Biophys. Biochem. Cytol. 9:409-414.

COCCINELLIDS AND APHIDS:

A Quantitative Study of the Impact of Adult Ladybirds (Coleoptera: Coccinellidae) preying on Field Populations of Pea Aphids (Homoptera: Aphididae)

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ABSTRACT

This paper examines the quantitative effect of predation by a ladybird beetle, **Coccinella trifasciata**, on field populations of pea aphid, **Acyrthosiphon pisum.** Field studies showed that no mathematical function, involving only the current densities of predator and prey, can predict the true predation rate. We studied the components of the predation process in detail, first in the laboratory, and then in the field. We derived a new, empirical (not theoretical) formula for predation rate, which includes predator and prey densities, predator voracity, prey age-distribution, and temperature. Temperature has a single effect on the rate of aphid development, but a double effect on the predation rate, so that coccinellids are much more effective predators at high temperatures, than at low. Field cage experiments, with known numbers of beetles, revealed that all current methods of counting adult coccinellids in the field greatly underestimate their true numbers. When this fault is rectified, the new formula correctly predicts the predation rate.

The study shows that it is possible to investigate a predator-prey relationship, in the field, in considerable detail, in order to predict the predation rate over a wide range of circumstances. The study reveals several sharp, qualitative, differences between the predation relationship observed in the laboratory, and the same relationship observed in the field. All laboratory studies must therefore be suspect, until verified in the field. In particular, arthropod predation studies must allow for effects of temperature on both predation rate and prey population dynamics. The coccinellid-aphid relationship permits no equilibrium, or steady state, so that conventional definitions of stability do not apply. The coccinellid's functional response is inherently unstable: the relationship is stabilized solely by a numerical response. Implications for biological control are discussed.

Contents

Introduction

Morris *et al.* (1963) pioneered the use of life tables for insects which have more or less discrete generations. Hughes (1963) and Hughes and Gilbert (1968) produced a "variable life-table" model of the cabbage aphid, which has overlapping generations. That model assessed the impact of a parasite on the aphid (Gilbert and Hughes 1971). The parasite had no serious effect on aphid abundance, which is restricted by competition and crowding. In similar analyses of other insects (Hassell 1969, Gutierrez *et al.* 1971, 1974a, b; Wratten 1973, Gilbert and Gutierrez 1973), natural enemies also had scant effect on prey numbers. Yet many parasites and predators effectively reduce the numbers of their prey (e.g. Frazer and van den Bosch 1973, DeBach 1974).

In 1972 we began to study field populations of pea aphid, *Acyrthosiphon pisum* (Harris) on alfalfa, *Medicago sativa* L. After the first year it was obvious (§ 1) that coccinellid predators significantly affect aphid density in the field. This paper analyses the predation process (§§ 4 & 5). This is the first time that Holling's (1964) "component analysis" has been applied to predation in the field, and tied into the life table approach of Morris *et al* (1963).

1. BACKGROUND

This section describes the field biology, and proves that the predation rate cannot be a function of current predator and prey densities alone.

Sampling and Field Biology

Alfalfa, *Medicago sativa* L., cv. Alfa was sown in 1971 at the University of British Columbia. The plot consisted of 18 rows each 25 m long and 1 m apart. The crop was cut three times during the summer of 1972, whenever about 10% of the plants were in flower. This approximated the commercial practice in the region.

A population of pea aphids, *Acyrthosiphon pisum* (Harris), became established on plants in 1971, overwintered as eggs, and reappeared in 1972. Pea aphids normally infest the actively growing terminals of alfalfa. We began sampling aphids in April and took samples about once weekly throughout the summer. A sample comprised 20 plastic bags, each containing ten terminals collected directly in the field. Pea aphids readily drop off a plant when it is cut, but care was taken to ensure that no aphids were lost. The bags were taken to the laboratory, where the aphids were beaten off the plants onto a sheet of paper, sorted under the microscope into four juvenile instars and adults, and counted. The fourth instar and adult aphids were separated into winged and wingless morphs.

Hymenopterous parasites, *Aphidius ervi ervi* Haliday, *A. smithi* Sharma & Subba Rao, and *Praon pequodorum* Viereck, attack the aphids. The parasites are themselves attacked by the hyperparasites *Asaphes vulgaris* Walker, *A. californicus* Girault, and *Dendrocerus* near *niger* Howard. To estimate the parasitization rate we dissected all aphids of the third and later instars in every sample, and recorded the numbers and sizes of parasite larvae they contained.

Large numbers of adult coccinellids invaded the alfalfa plot between May 9 and July 18. The commonest species were *Coccinella trifasciata perplexa* Mulsant, *C. t. subversa* Leconte, *C. undecimpunctata undecimpunctata* L., *C. johnsoni* Casey, *C. californica* Mannerheim, and *Cycloneda munda* Say. To sample for coccinellids, observers walked on either side of each row of alfalfa counting all visible beetles. At the same time we counted the parasite mummies. Aphidiid parasites pupate inside or below the dead, eviscerated host aphid, which is transformed into a shell, or "mummy". This gives a second estimate of the parasitization rate.

At the start of the season, aphid numbers began to increase (Fig. 1, May 9-25). After the beetles had arrived (May 25-31), the aphid population declined to a low level, which it

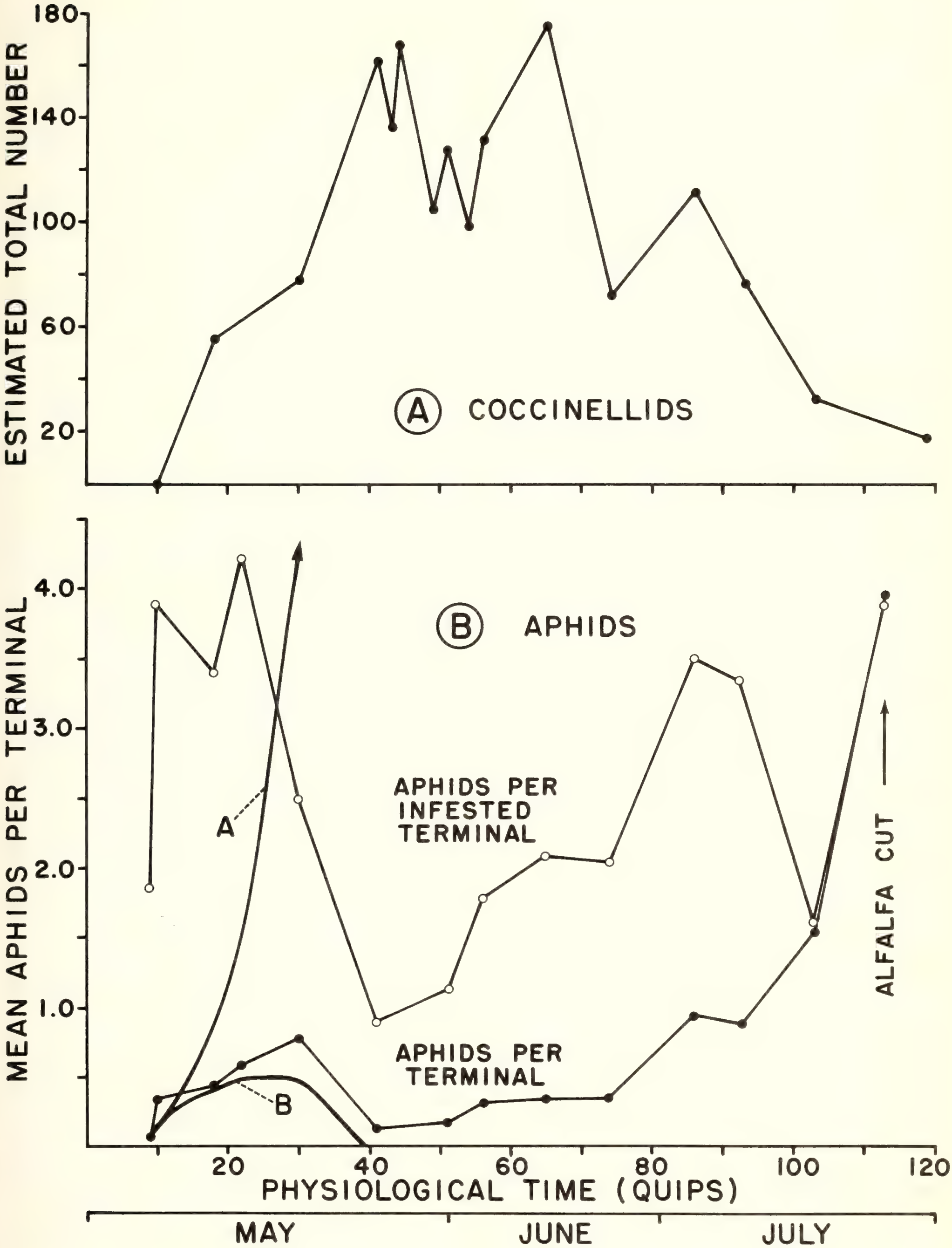


FIGURE 1A. Coccinellids of all species in the whole plot; 1B, aphids per terminal, both in 1972. Each aphid sample contained at least 160 plants. The fall in 'aphids per infested terminal' beginning at q 84 is probably due to an inaccurate estimate of p (see text). Curves A and B (1B) are computed by Appendix 1 in the absence and presence of coccinellids.

maintained throughout the period of maximal coccinellid numbers (May 31-June 21). Thereafter, coccinellid numbers fell sharply, and the aphids again increased (June 21-July 18) until the alfalfa was cut. We shall concentrate on the early period shown in Fig. 1. Later in the season, the aphids were attacked by many other natural enemies of aphids, eg. Chrysopids, Nabids, Mirids, Spiders, Syrphids, and Coccinellid larvae. At the same time, the alfalfa plants grew so big that the aphid samples became unreliable.Nevertheless, the aphid population dynamics during the first half of the season are sufficiently simple to permit some understanding of the underlying processes. Our task is to explain the course of aphid numbers shown in Fig. 1.

Biological parameters

An aphid goes through four instars before becoming adult. We estimated the duration of each instar, and the pattern of adult fecundity, by rearing aphids in the laboratory at each of four constant temperatures (10°, 15°, 20°, 25°). The development rate increased linearly with temperature in this range, so that a given instar required a constant amount of 'physiological time', measured in day-degrees above a threshold temperature of 4°C (Campbell *et al.* 1974). Since this physiological time-scale is the aphid's own time-scale, we adopted it for this study. The first three instars each took about the same amount of physiological time, which we adopted as the aphid's basic time-unit, one 'instar-period'. The fourth instar took longer; 1½ instar-periods for wingless aphids, and 1¾ for winged. To accommodate these varying periods, we adopted one quarter-instar-period, or 'quip' (q), as the unit of physiological time. For the pea aphid at Vancouver, one quip equals 6.56 day-degrees C above the threshold temperature of 4°C.

Parthenogenetic wingless aphids mature after 18 q, begin to reproduce at 19 q and can survive to 90 q. The physiological time-scale compensates for the effects of temperature, not only on development, but also on reproduction. For reproduction, the compensation is not quite perfect, but on the physiological time-scale, the time pattern of reproduction was nearly the same for the four temperatures. In other words, on this scale, both the total fecundity and the reproductive pattern are effectively independent of temperature.

Population Model

These development times and fecundities allowed us to predict the rate of aphid increase, assuming that all individuals survive to age 90 q. This we did by a simple simulation model (Appendix 1). We first converted calendar time in the field to physiological time, using a computer program (Appendix 2) which fitted sine curves to daily maximum and minimum air temperatures, and integrated them above the developmental temperature threshold (Morris & Bennett 1967). Each day in the field calendar was converted to its equivalent in physiological time, beginning arbitrarily on May 1, 1972.

There was a large discrepancy between the aphid model (curve A, Fig. 1) and observed aphid densities. The data indicated heavy mortality while the coccinellids were present. The age distributions (not shown) agreed. From 0-22 q, the aphids increased in numbers (fig. 1) at the rate predicted by the simulation model. No beetles were seen until 20 q. During 20-40 q, there was an influx of beetles, and the aphid population began to decline. The beetles remained in large numbers during 40-70 q, and the aphid population remained low. Most of the beetles left the plot between 70-120 q, whereupon the aphid population resumed its exponential increase.

The beetles had some direct effect on the aphids, as indicated by changes in the average number of aphids per *infested* terminal. The probability p that a sample unit of n terminals contains no aphids is f^n, where f is the frequency of uninfested terminals. From the values of p observed in the samples we estimate the corresponding f and $p^{1/n}$. The average number of aphids per terminal is then divided by (1-f), to estimate the average number of aphids per *infested* terminal. During the period May 9-19 (9-22 q, Fig. 1), that number increased from 1.9 to 4.2, since the population consisted of adults and their progeny, living on the same plants. The frequency f of unoccupied terminals was considerably greater than would be predicted by a random, i.e. Poisson, distribution with the observed mean number of aphids per terminal. When the beetles arrived during 20-40 q, the average number of aphids per infested terminal fell to its minimum level of one, a probable result of the activity of the beetles. When beetles search plants, they catch only a small proportion of the aphids and scatter the rest on the plants. When the beetles left, the aphids became aggregated again as the mean density increased.

At first the simulation model used the simplest possible predation function. The beetle's voracity was measured by feeding average-sized aphids to adult *C. trifasciata* in the laboratory. It was recorded as a number of aphids; later, we used biomass. If there are b beetles per terminal, and each eats k aphids per q, the demand for aphids will be kb per q. If there are a aphids per terminal, each aphid must expect to be eaten kb/a times per q. If the beetles search at random, the aphids will escape predation with a frequency equal to the zero term of the Poisson distribution, which in this case equals exp $(-kb/a)$, a crude expression that worked well in previous cases (Hughes &

Gilbert 1968, Gilbert & Gutierrez 1973). When this survival rate, calculated in the model for every q, was applied in the population model, the aphid numbers rapidly decreased to zero (curve B, Fig. 1). But the field counts of beetles probably underestimated the true numbers, since some beetles escape notice. We therefore concluded that:

(1) The beetles were sufficient in timing and numbers, to explain the early season reduction in the aphid population.

(2) The success of the beetles in finding aphids at low density was considerably less than that predicted by random search.

(3) No conceivable mathematical function which includes only the current average numbers of predators and prey, can predict the survival rate of the prey: aphid and beetle numbers were much the same at 30 q and 90 q, yet at 30 q aphid numbers declined, and at 90 q they increased (Fig. 1). The true predation rate must therefore be affected by some other factor, which might be some characteristic of the predator or prey populations, e.g. age distribution or aggregation (cf Hassell & May 1973), or some environmental factor. We decided to study the predation process in detail.

2. PREDATION IN THE LABORATORY

Holling (1966) has shown how to study the actual process of predation with great realism. Rather than invoke theoretical functions and assumptions, Holling studied the detailed behaviour of the predators and prey, to determine the important biological parameters which predict the 'functional response'. But his approach is too complex for application in the field. We needed a simpler model of predation, at once realistic but simple enough for field use. We decided to study predation in an artificial arena to identify those essential components which must unavoidably be measured in the field. To avoid duplication of symbols, we shall freely mix algebraic and FORTRAN notations.

Methods

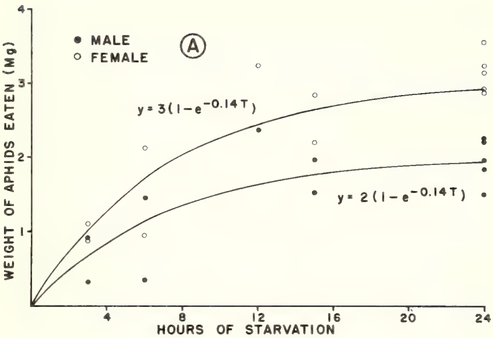
The tests were made in standard greenhouse flats each containing 12 small alfalfa plants arranged in a 3 x 4 grid. Each plant had a single stem with many of its leaves removed, so that the aphids could easily be seen. To make the aphids visible when on the ground, the soil was covered with white sand. The sand was kept wet because the beetles made poor traction on dry sand. The aphids and beetles were confined by a transparent plastic cage 29 cm x 45 cm and 21 cm high. To prevent the insects from walking up the walls of the cage, its lower rim, which rested on the sand at the edge of the flat, was coated with Fluon (a brand of polytetrafluoroethylene dispersion supplied by Imperial Chemical Industries Ltd.). All the coccinellid species found in the field, except one, readily flew off the plants and landed on the cage, so nullifying the test. The exception was *C.u. undecimpunctata*, which we adopted for the laboratory work.

We re-defined 'hunger' as that weight of aphids which a beetle will voluntarily eat until satiated. We established the hunger curve by feeding forty beetles until they refused to eat aphids presented directly to them, then starving them for various time periods at 24 ± 1°C, and weighing them. Each was again fed to repletion, and its increase in weight recorded. After 24 hours' starvation, males of *C. u. undecimpunctata* will eat a maximum of 2.0 mg. of aphid on average, and females about 3.0 mg. We therefore write HGR = 2.0xH for males, and 3.0xH for females. The curve for H (Fig. 2A) is of the type H = 1 - exp*(-kt)* (Holling 1966). Thus we shall use H for the *relative* hunger, the same for both sexes, and HGR for the *absolute* hunger.

The laboratory tests were done in a controlled room at 24.0 ± 1°. We placed aphids in known numbers and instars on the 12 plants, and left them to settle. Then we chose a beetle of known sex, which had been starved for a predetermined time at constant temperature, so that its initial hunger HGR could be estimated (Fig. 2A). Dixon (1959) has shown that a coccinellid changes its search pattern when it makes contact with an aphid, even if it does not capture the aphid. Therefore, each time the beetle climbed onto a plant, we recorded its hunger HGR and the time TLC since the beetle last contacted an aphid. At the start of each test we allowed the beetle to make contact with an aphid but not to capture it. Both HGR and TLC were thus established at the start of each test.

The beetle was placed on the sand inside the cage, where it began to search the plants for aphids. For every visit to a plant, we recorded the following: plant height; the number of trifoliate leaves; numbers and instars of the aphids on the plant at the start of the visit; numbers and instars of aphids which were eaten, which fell from the plant but returned to it, and which fell and left the plant for another; whether or not the beetle made contact with an aphid on the plant; and the lengths of time which the beetle spent in searching the plant, stationary on the plant, moving on the ground after it had left the plant, and stationary on the ground.

A beetle is stationary when it is eating, cleaning its appendages or resting, usually when it is not hungry. A beetle detects aphids only when it contacts them with its maxillary or labial palps. After contacting an aphid, the beetle scours the locality very thoroughly, making frequent turning movements. When a beetle searches a plant, many of the aphids on



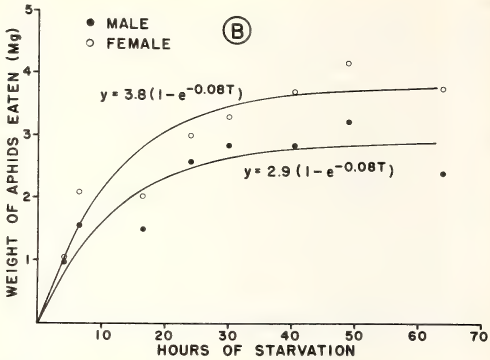


FIGURE 2A. Hunger, HGR, curves of Coccinella **undecimpunctata** at 24°C; B, C. **trifasciata** at 20°C. Each point is a mean value from about 40 beetles. The physiology underlying the variability in hunger has not been explored, but females tend to vary more in weight than males because captive females may lay eggs, and may or may not eat them.

that plant fall off, and so avoid predation. The aphids rarely left plants unless disturbed. We tallied the aphids as they moved from plant to plant, by means of counters which were moved correspondingly from square to square of a checkerboard. In this way, the current population of any plant was known whenever a beetle climbed onto it. A beetle can capture and eat aphids of all sizes, and the average time taken to consume an aphid is directly proportional to the aphid's weight (Fig. 3). But not all pea aphids are equally at risk. The older and larger aphids drop from plants much more readily than the young ones, so that first and second instar nymphs are those most vulnerable to predation. Large aphids which have fallen off a plant can find their way onto a new plant much more readily than can small aphids. In particular, a winged adult is largely immune from predation, partly because it readily falls off the plant, and partly because the beetle usually seizes the aphid by its wings and so cannot eat it without first letting go, whereupon the aphid usually escapes.

We made fifty such laboratory tests, each lasting an hour or more. Altogether, 2,020 plant visits were recorded, with varying numbers and distributions of aphids. When two beetles were placed in the cage together, they searched independently.

Analysis

The next step is to determine, from the data collected in the laboratory tests, the 'components' of the predation process (Holling 1966). The measurements taken were very variable, but regression analysis revealed the following relationships, which were similar for both sexes. The probability, PC (Table 1) that a beetle would make contact with an aphid on a given plant was proportional to the beetles' hunger, HGR, and to the number of aphids on the plant. That probability was never very

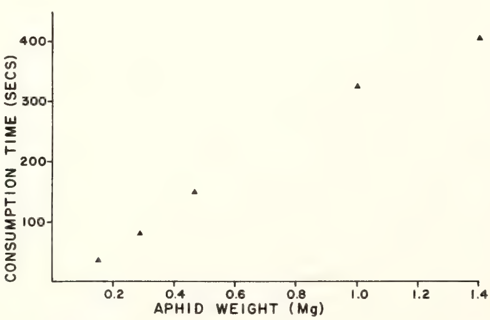


FIGURE 3. Times taken by adult C. **undecimpunctata** to eat various instars of aphid at 24°C. Each point is a mean of between 9 (adult) and 70 (1st instar) aphids.

TABLE 1. Variable Names and Their Meaning

AWT—weight (mg) of one aphid; which varies with instar (Table 2).
HGR—hunger (mg) of aphid (Fig. 2).
H—hunger, on a relative scale from 0 (replete) to 1 (fully hungry).
PC—probability that a beetle will make contact with an aphid.
PE—probability that a beetle will eat an aphid.
PL—probability that an aphid will leave a plant.
TLC—time (sec) since a beetle last contacted or ate an aphid.
TS—time (sec) spent searching a plant.

great. If no contact was made, the time, TS, which the beetle spent on the plant, increased with plant size and decreased with TLC, the time since last contact. According to the regression analyses, 'plant size' is best expressed as the simple product of plant height and the number of leaves. The probability, PL, that any given aphid shall leave a plant increases with TS. If contact was made, the probability, PE, that the beetle ate any given aphid was proportional to HGR. Since older aphids fell off and escaped predation more easily than younger ones, the probabilities PL and PE had to be corrected by factors appropriate to the different aphid instars (Table 2) present on the plant.

When no aphids were eaten, TS increased with plant size: when some were eaten, TS increased with the total number of aphids on the plant, and additional time elapsed while the beetle ate its prey and cleaned its mouth parts. Time spent in eating was proportinal to the biomass of the aphid eaten (Fig. 3). Whether or not any aphid was contacted, PL increased with TS: but PL (with contact) exceeded PL (no contact), because the beetle searched the plant more thoroughly after it had made contact. The beetle also spent time on the ground, while moving between plants. If the beetle was hungry (HGR was large) or if it had recently contacted an aphid (TLC was small), it spent a relatively short time on the ground.

These relationships were built into a simulation model of the predation process. Since the relationships are all linear, the model uses average values; for example, TS is actually very variable, even allowing for plant size, etc., but the model uses the average value appropriate to the particular circumstances. Since the model represents events in the laboratory only, we shall not describe it in detail: but later we shall present a similar, but simpler, model of predation in the field (Appendix 3). The laboratory model was checked, and the values of PE and TS were altered in order to reproduce the timing and frequencies of eating and leaving observed in all the various experimental conditions.

We then analysed the laboratory model to see which features could safely be omitted—especially those difficult to measure in the field. The most important conclusion was that although contact certainly influenced the behaviour of individual beetles, its effect could be absorbed into the values of PE and PL, and so the whole mechanism of contact could be omitted, provided the PE and PL were modified appropriately. This was fortunate, since it would be almost impossible to observe TLC in the field. However, the contact mechanism might cause PE to increase with the number of aphids on the plant. But an analysis of the numbers of aphids eaten on plants with varying initial numbers of aphids, showed no tendency

TABLE 2. Values of AWT, FACTE and FACTL

Average weights (mg) of aphids in the field (AWT) in 1973 and 1974. Aphids in the laboratory were generally lighter (cf. Appendix 3). When a beetle visits a plant, each aphid on that plant is eaten or leaves the plant, with *relative* frequencies FACTE and FACTL respectively. The frequencies were estimated during the laboratory tests. They must be multiplied by appropriate constants to give absolute frequencies PE or PL.

Aphid	AWT	FACTE	FACTL
Instar 1	0.17	1.68	0.64
Instar 2	0.33	1.28	0.68
Instar 3	0.91	0.75	1.05
Instar 4	1.88	0.52	1.13
Adult wingless	3.82	0.46	1.29
Adult winged	2.15	0.36	1.97
Mummy	1.88	0.57	—

for PE to vary; except that once one aphid had been eaten, other aphids on the same plant were slightly more likely to be eaten. The effect could be ignored, leaving hunger as the sole driving mechanism.

3. PREDATION IN THE FIELD

This section converts the laboratory predation model to represent the same process in the field, and uses it to predict the survival rate of aphids in the field. As far as possible, we measured all the model's parameters again, by watching and timing beetles in the field.

Timing

In the first series of field observations, we watched beetles searching at a low aphid density of about 0.2 per terminal. One observer followed the beetle's progress over the vegetation, while another timed and recorded each visit to a new plant. In this way, we estimated the average time, TS, which a beetle spends on a plant when no aphid is eaten. The estimate of TS, i.e. 51.3 sec (Appendix 3), is the average of 504 plant visits.

It was not necessary to measure the sizes of the alfalfa plants in the field. They were generally larger than those in the laboratory, with more leaves and branches. But the beetles did not search the entire plant; instead, they primarily searched the sunlit canopy of contiguous leaves and stems, where most of the aphids were. Most importantly, neighbouring plants touch, and so both aphids and beetles walked or flew freely from plant to plant. The beetles spent no time on the ground while searching for aphids, and the time spent on any plant did not depend on that plant's overall size.

Probability of Capture

In another series of field observations, we seeded lengths of row with high densities of aphids, and watched the beetles search for them. The average density of aphids on these plants was determined afterwards by sampling. That density, multiplied by the total number of plants visited (286), gave the total number of aphids at risk, 1746. Of those, 32 were actually eaten, giving a frequency PE of capture of 0.018. In the model, PE equals a constant times the relative hunger H. This constant is tentatively deduced as follows: since the beetles flew in from other parts of the field where aphids were scarce, we assumed that the beetles were very hungry, with H=0.88, corresponding to 15 h starvation as set initially in the model (Appendix 3). The constant must therefore be 0.018÷0.88, so that PE=0.0205 x H. This equation is re-examined in Appendix 4. The value of PE is much lower in the field than in the laboratory, because in the field a beetle makes only a cursory search of each plant, but searches many more plants in a given time. The same series of field observations gave the average time spent on one plant when aphids were eaten. In the laboratory model, PE was a function of time searching, which in turn was a function of plant size. In the field model, PE is no longer affected by plant size, and therefore the distinction between time searching and not searching is no longer required. Regression analysis of the field data shows that the time spent on a plant increases with the number of aphids eaten; so in the model, it appears as a linear function of the total weight of aphids eaten (Fig. 3).

Probability of prey movement

We could not directly measure PL, the probability of an aphid leaving a plant, because it was impossible to see how many aphids left during a visit by a beetle. However, PL must depend on the beetles' searching behaviour in much the same way as PE. Therefore, to estimate PL in the field, we took the frequency with which aphids fell off the plants in the laboratory, and changed it in the same proportion as the observed change in PE. The resulting value of PL must clearly be suspect; fortunately, analysis of the model showed that within reasonable limits, the value of PL had little effect on the predation rate. This does not, of course, imply that the aphids' behaviour in leaving the plant did not affect the predation rate, for that behaviour affected PE as well as PL. Having thus obtained overall values for PE and PL, we used the same factors (Table 2) as were observed in the laboratory, to compute the probabilities for each aphid instar. This was unavoidable, since it was impossible to count all the aphids of each instar on a plant in the field without disturbing them. However, these corrections were reasonable, because the relative frequencies depended more on the behaviour of the aphids than of the beetles. Most of the aphids captured by beetles in the field, were the youngest, as in the laboratory.

We now use these rules to develop the field model for predation (Appendix 3). It is impossible to determine the sex of each beetle encountered in the field without unduly disturbing it, and so the field model assumes a 1:1 sex ratio.

Effects of Temperature

The model describes events during one q at 18.5°C, the average temperature during the field observations. But the times spent on each plant are related to the speed at which beetles move and thus to temperature. We placed beetles of the three species on vertical poles in the laboratory, and timed their walking speeds at different temperatures. The result (Fig. 4) shows that the beetles' walking and searching speed has about the same temper-

ature threshold as the aphids' rate of development, and so we may use the same physiological time-scale for both predators and prey. The field predation model therefore describes the predation process during one q at any ambient temperature.

Temperature has an additional effect on coccinellids. At low temperatures, many of the field beetles are inactive (Fig. 7), even though they are capable of motion (Fig. 4). The physiological time-scale thus allows for the effect of temperature on the beetles' speed of search when active, but not for the variable amount of activity. Therefore, the number of beetles actually present at any given time must be multiplied by an activity coefficient, to give the effective number of active beetles. At first, we used the data in Fig. 7 to estimate the activity/temperature relation, with a temperature threshold of 8.7°C. But later we found (§ 5) that the counts in Fig. 7 are still biassed. The field cage experiments in § 5 demand that the temperature threshold be reduced to 4°C, the same value as for beetle movement. The algorithm used to calculate the approximate average temperature, for each q in the field, appears in appendix 5. Despite several attempts, we have not obtained a direct estimate of the activity/temperature relation, which is complicated by effects of sunshine and by some kind of circadian rhythm. But the fact that temperature has a double effect on the beetles, and a single effect on the aphids, has important consequences for the predator-prey relationship (§ 6).

Analysis

The aphid survival rates, predicted by the field predation model, will now be applied to the aphid population model. It would be possible to build the predation simulation model directly into the aphid population model, by calculating the survival rate *de novo* whenever it is needed. To do so would take impracticable amounts of computer time. The results of the predation model are best expressed as empirical functions which can be used directly in the population model.

The predation rate must depend on beetle density, and on aphid age-distribution, density and possibly aggregation. All these parameters must therefore appear in the empirical function. The problem is not really so complex. For the model shows that the overall survival of a mixture of aphids of different ages is about equal to the weighted average of the predicted survival rates of the individual age groups. For example, it shows that the survival of 0.2 adult + 0.6 instar I aphids/plant (total density = 0.8) is, very nearly, ¼ of the survival of 0.8 adults/plant + ¾ the survival of 0.8 first instar/plant. Moreover, the survival rate must be squared when the beetle density is doubled, since the beetles search independently of each other. The model shows just that effect, which incidentally proves that the model's time-step of one q is short enough, as far as the beetles are concerned: that is, within one q, no beetle can destroy so many aphids that it seriously reduces the number of prey available

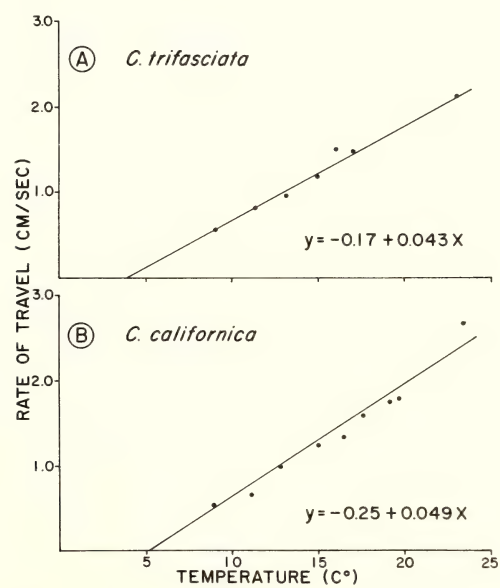


FIGURE 4. Effect of temperature on coccinellid walking speeds. Each point is a mean of about 40 observations.

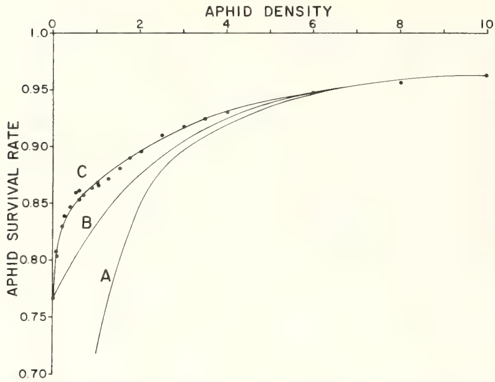


FIGURE 5. Survival rates per q, computed by Appendix 3, of second-instar aphids attacked by C. trifasciata. Coccinellid density=1/60 plants. Curves A, B, C are fitted in Appendix 4.

to other beetles. These circumstances permit us to analyse the predation model, using beetles at a fixed density, and aphids of one instar only. We used second instar aphids, and beetles at the highest density observed in the field, *viz.* 1 per 60 plants. We chose this case because it gives high aphid mortality, and therefore accurate estimates of survival rates. For each aphid density, the model (Appendix 3) was run many times, using different random numbers: the average survival rates predicted for varying aphid densities are shown in Fig. 5. They do not lie precisely on a smooth curve because they are estimated by this 'Monte Carlo' method, which estimates the survival rate from a finite number of trials.

The effects of aphid distribution or aggregation on predation rate are slight according to the field predation model. At average densities of less than one per plant, the survival rate is slightly lower when the aphids are highly aggregated on few plants, than when well spread out on isolated plants. That is because, having found one aphid, a beetle easily finds the others on the same plant. There is no such effect at high aphid densities, when a beetle can find enough aphids irrespective of their distribution.

By contrast, the laboratory predation model showed a great effect of aphid distribution (Fig. 6): the predation rate might be three times greater when the aphids were clumped, than when they were well spread out. This was an effect of timing, which persisted after the contact mechanism was eliminated from the model. It arose because, in the laboratory, the beetles could not climb directly from one plant onto another, and therefore spent a long time

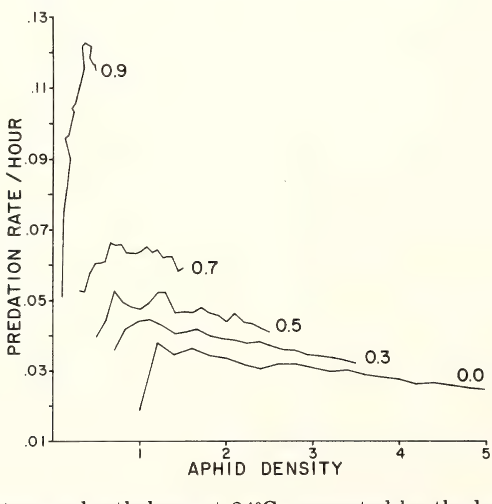


FIGURE 6. Predation rates per beetle-hour at 24°C, computed by the laboratory predation model, of second instar aphids when attacked by **C. undecimpunctata.** Coccinellid density = 1/100 plants. Different lines refer to different initial proportions of uninfested plants, as marked.

on each plant. In the field, however, the beetles moved directly from plant to plant, and thus visited many more plants for each aphid caught.

A predator-prey relationship might indeed be stabilized by predators scattering their prey (cf. Huffaker, Shea & Herman 1963), but not in our alfalfa plot, where the predators ranged freely and quickly over the area. We therefore ignored the slight effect of aphid distribution found in the field predation model, because it was equivalent at most to a 5% increase in beetle density, which is well within the accuracy of our field counts.

The next task was to fit an empirical function for survival from predation. We already knew how to deal with varying beetle densities and mixtures of aphid instars, so we needed only to fit a curve to the predicted points in Fig. 5. This was done (Appendix 4) and the resultant expression for the survival rate of aphids of instar I is

$$\underline{s} = \exp\left(\frac{-5.7}{AWT(\mathrm{I})} \times \frac{\mathrm{b}}{\mathrm{a}} \left(1 - \exp(-\underline{k}a)\right)\right)$$

where $\underline{k} = 2.6 \times AWT\,(\mathrm{I}) \times \underline{FACTE}\,(\mathrm{I}) \times (0.654 + 0.026/\underline{a} + 0.075))$. This expression for s gives the fitted curve C in Fig. 5. By contrast, curve A is the random search curve, discarded in§1.

During the period 1 - 121 q of 1972 (Fig. 1), field densities of aphids were always less than one per plant. At these densities, the survival rate predicted by the model is very much higher than the random rate (Fig. 5), for the following reason: random search implies that the beetles can find aphids immediately, whereas the model imposes a time restriction. At low aphid densities, there is far too little time within a single q for a beetle to visit enough plants to find all the aphids it needs. Little wonder that random search in § 1 incorrectly predicted the demise of the aphid population.

4. BEETLES AND APHIDS COMBINED —FIRST ATTEMPT—

This section tries to reconcile the predicted predation rate with the observed survival rate of aphids in the field. By the time we had completed the field predation model, we had obtained population records from a new season which showed that the 1972 beetle counts were inaccurate. We therefore shall not use the 1972 data further, but instead describe the field methods used in 1973.

Sampling and field biology

Two plots of Alfa alfalfa were sampled 0.8 km apart on the grounds of the University of British Columbia. Plot 1 was that sampled in 1972. Plot 2, sown in 1972, consisted of 26 rows each 15 m long and 1 m apart. When the alfalfa was cut infrequently, the plants produced numerous lateral branches which made our sampling units of plant terminals ambiguous and ill-defined. We therefore departed from standard commercial practice in 1973 by cutting more often, whenever the plants reached about 1 m in height. All the rows were cut simultaneously on plot 1, but even- and odd-numbered rows of plot 2 were cut alternately, so that half the rows always contained tall plants bearing aphids. We sampled the even and odd rows of plot 2 separately, whereas plot 1 was sampled as a unit. Aphid samples were taken by cutting individual plant terminals and beating aphids off. The small-scale distribution of aphids over the plants does not seriously affect the predation rate in the field (§ 3). We looked for consistent large-scale patchiness, by taking samples from a regular grid pattern over the whole alfalfa plot. There was none. The number of terminals per sample varied between 40 and 400, according to the aphid density. Aphid samples were taken from each plot at least once a week, but 2-3 times a week during warm periods, when aphids were developing quickly.

The 1972 method of counting coccinellids and parasite mummies gave reproducible results; but we later found it to be inaccurate because mummies are easily overlooked and beetles are most easily seen when temperatures are high. Instead, we randomly chose between 40 and 70 short (30 cm) lengths of row, and searched them thoroughly for beetles. Beetle numbers changed rapidly (Fig. 8), and so we sampled almost daily during the main period of attack. Each beetle was classified by species, and according to whether it was moving or stationary when first sighted (Fig. 7). The ambient temperature inside a Stevenson screen placed on the ground in the plot was also recorded. The same species of coccinellids were found as in the previous year, but since *C. johnsoni* was observed freely mating in the field with *C. californica,* we counted them as one species. The dominant species was again *C. trifasciata,* which was three to five times as common as *C. californica.* The other species were comparatively rare.

We counted mummies at least twice weekly by the same method used for beetles. The mummies were classified as unemerged, emerged or preyed upon. The latter are easily recognized because the edges of the irregular holes made by coccinellids or the punctures made by chrysopids and nabids are darkly stained; the circular emergence holes of primary parasites and the irregular emergence holes of hyperparasites are not stained. We took samples of unemerged mummies from time to time and reared them at constant temperature, to estimate the sex-ratio of the parasites, their age-distribution, and rates of hyperparasitization.

The numbers of plants per foot of row were counted at various times through the season, to

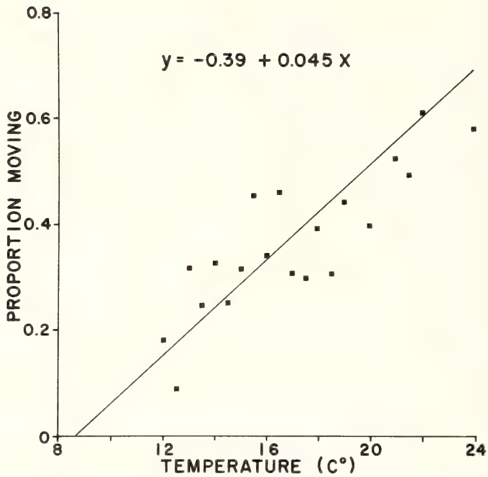


FIGURE 7. Effect of ambient temperature on proportion of C. trifasciata observed moving in field counts. For absolute numbers, see Fig. 10.

reconcile the two methods of sampling, *viz.* aphids/terminal, and beetles/length of row. We made checks by enclosing all the plants in one-foot lengths of row in plastic bags, cutting the plants at the base, and counting all the aphids and mummies found in the bags. Consistently, the average number of mummies/ft. was about twice that observed in the regular counts, mainly because mummies on the underside of the leaves or low on the plant, had been overlooked. The regular counts therefore are multiplied by the appropriate factor to correct for this under-estimate. Equally consistently, and irrespective of average plant height, total numbers of aphids/ft. were only half those predicted by multiplying the number of plants/ft. of row by the average number of aphids/plant derived from aphid samples. This is not unreasonable, since tall plants are much more heavily infested than the short ones. We therefore divided the counts of plants per foot by the appropriate correction factor to give the number of effective plants per foot.

Synthesis

Next we insert into the population model the aphids' rate of survival from predation, calculated by the field predation model, and using the new beetle density *b*. We make no distinction between the different species of coccinellids, but equate them all to *C. trifasciata*, which was always in the majority.

On plot 2 (1973), a generation of parasites matured during the period of coccinellid attack (Fig. 8). The mortality due to parasitism must therefore be inserted into the aphid population model. The best estimate comes from the field counts of mummies, and we therefore include in the model an amount of parasitization which reproduces the observed pattern of parasite mummies, both in time and numbers. We used the following method: the developmental threshold for the parasite *Aphidius ervi* is 4.2°; thus the two physiological time-scales are in proportion throughout the period of beetle attack. The length of time spent by a parasite in the mummy can therefore be equated to a fixed amount of the aphid's physiological time, namely 15 q.

It is the juvenile aphids between ages 4 q and 17 q which bear the brunt of the parasite attack (A. Campbell, pers. comm.). Laboratory tests showed that parasitized aphids, collected in the field in their fourth instar, can produce up to 26 progeny before the parasite pupates and kills the aphid. We therefore represent parasitism in the following way: parasitized aphids are not distinguished from unparasitized aphids in the model until the time comes for the parasite larvae to pupate. Then a proportion of aphids in the appropriate age-range is converted into parasite mummies. The correct proportion of parasitized aphids will thus produce their appropriate number of progeny before they die. The proportion of aphids converted into mummies, varies with time. The proportions were chosen by trial-and-error, to give the observed numbers and time-pattern of mummies in the field.

The parasite mummies are themselves subject to coccinellid attack, and therefore form a distinct class of prey in the predation model. The model gives the observed proportion of preyed-upon mummies, only when the predation rate on mummies is reduced to one-third the predation rate of first instar aphids (Table 2). Unlike healthy aphids, parasitized aphids often move to the upper surfaces of leaves, where beetles rarely search. The mum-

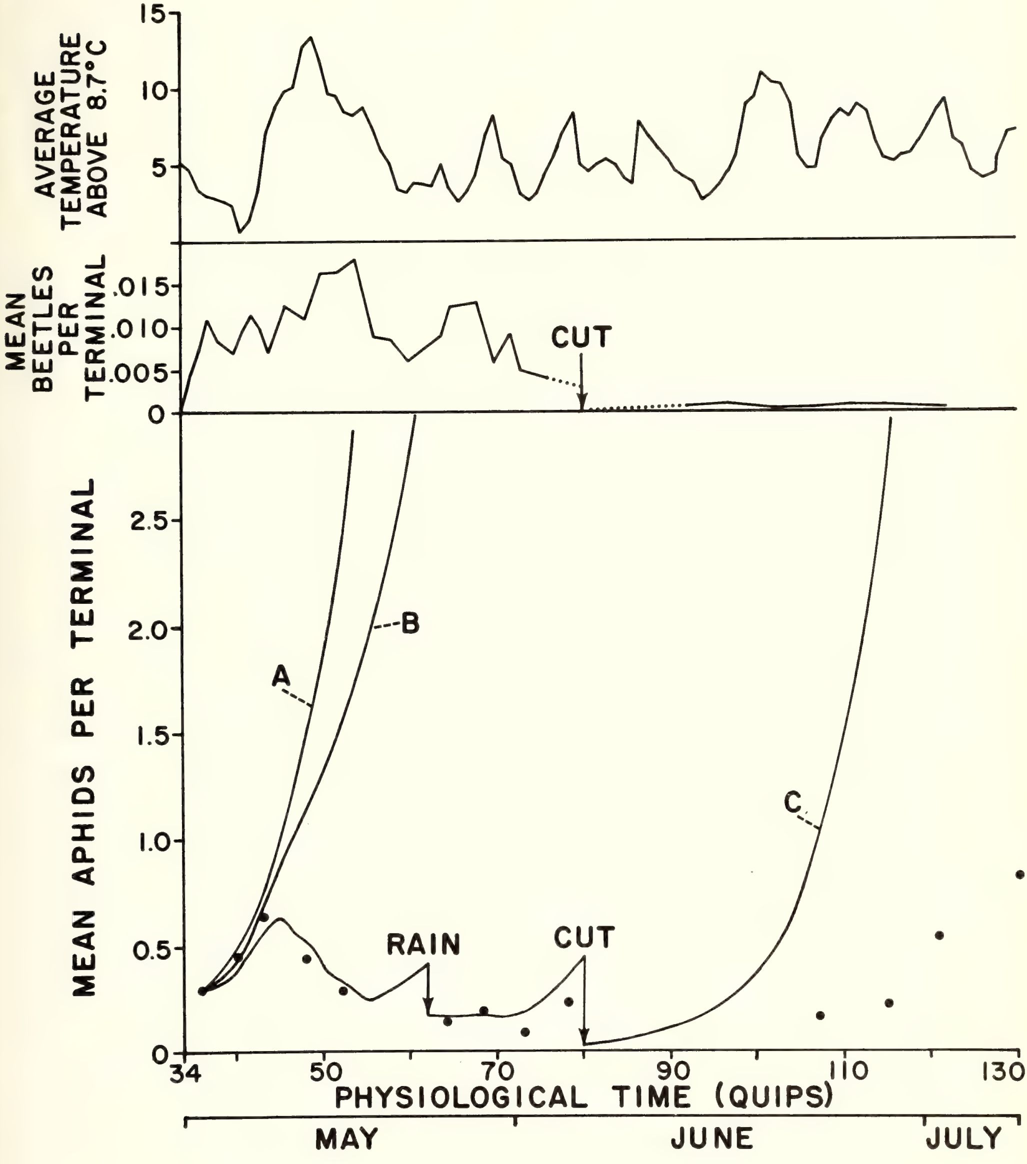


FIGURE 8. Numbers of beetles and aphids in 1973, plot 2, even-numbered rows. The upper section shows the weighted average temperature/q. TEMP, above the activity threshold 8.7°C. It is computed by Appendix 5 and used in Appendix 6. The middle section shows the field counts, COCC, of beetles/plant. The temporary increase in beetle numbers during q 60 - q 65 occurred when the odd-numbered rows of alfalfa were cut, and the beetles moved to the uncut even-numbered rows. The lower section shows the observed numbers of aphid/plant, together with three curves computed by Appendix 6. The population model reproduces the effect of heavy rain at q 62 by imposing the appropriate survival rate on the aphids; similarly when the alfalfa was cut at q 80. These survival rates were found empirically by comparing aphid densities before and after the event. Precisely the same survival rates were observed on plot 1 and on the odd-numbered rows of plot 2.

mies therefore suffer an unexpectedly low rate of predation.

Fig. 8 shows the population dynamics of aphids and beetles on the even-numbered rows of plot 2, during and immediately after the period of beetle attack in May and June, 1973. The physiological time-scale starts on March 1, 1973. The pattern of events was very similar on the odd-numbered rows of plot 2, and on plot 1, i.e., the coccinellids arrived when the aphids were increasing in numbers, and the aphid population then declined, the beetles left, and the aphids again resumed their exponential increase. The same thing had happened in 1972 (Fig. 1).

Aphid numbers never exceeded an average of 0.7 per terminal during the period shown in Fig. 8, and so no density-dependent competition for food can be invoked. The population model simply combines fecundity rates for the aphids with the predicted survival rates from coccinellid and parasite attack. To explain the observed changes in aphid numbers the model must predict rates of survival from parasitization and predation, equal to those which the aphids actually experienced in the field. The predicted effects of parasitization and predation are too low to prevent a steady increase in simulated aphid numbers (curve B, Fig. 8). If the number of beetles is arbitrarily quadrupled, the model simulates the observed aphid numbers well enough for the period 15-79 q during the beetle attack (curve C, Fig. 8). We are out by a factor of four.

The curves in Fig. 8 were computed (Appendix 6) using the laboratory estimate of aphid fecundity. Much later we found (§ 5) that fecundity in the field is consistently only 30% of the laboratory estimate. This largely explains why curve C (Fig. 8) rises too fast during the period 80-130 q, when few coccinellids were seen. But it does not explain the discrepancy during the period of beetle attack. Using the true aphid fecundity, the observed number of beetles must be doubled, if the population model is to reproduce the field data. Fig. 9 shows the results of laboratory experiments to test the effect of high temperatures on aphid fecundity. There was no effect until the temperature exceeded 27°C, which was the highest temperature observed in the field. Thus the new population model gives a better approximation of the true mortality, than the 'random search' of § 1; but it now seems to underestimate the beetles' destructiveness.

5. BEETLES AND APHIDS COMBINED —SECOND ATTEMPT—

This section reconciles the predicted predation rate with the prey population dynamics.

In 1974, we erected four cages on plot 1. Each cage was 5 x 6 x 2 m high, and contained three rows of alfalfa each 6 m long. The cages were covered with translucent plastic and screening, which together admitted light, fresh air and rain. The temperatures recorded in the cages were sometimes a few degrees higher, during the day, than those in the field outside. We used the cages to compare aphid population dynamics in the presence and absence of known numbers of coccinellids. These were first-generation beetles bred in the laboratory, partly to eliminate parasitism, but mainly because we could not rely on collecting enough beetles from the field, early in the season. Figs. 11-13 show the results of three successive experiments, made for different purposes and in different conditions. The first was to determine the number of ladybirds needed to make an obvious reduction in aphid numbers, without driving them down too low. It also examined the possibility that the aphids might suffer mortality, over and above the direct predation, when beetles drive them off the plant; for example, when the youngest aphids fall off a plant in the laboratory, they have difficulty in finding a new plant. This explains why they fall off so much less readily than the older aphids (Table 2), even though they suffer a greater rate of predation in consequence. The weather during this first experiment was cool and wet.

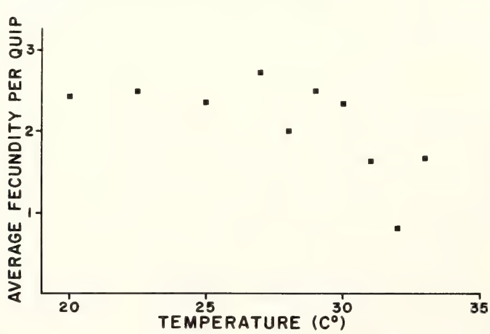


FIGURE 9. Effect of temperature on fecundity of aphids collected in the field and kept at constant temperature in the laboratory. Each point is a mean of about 20 adult aphids.

The second experiment, in warmer weather, was done in duplicate to see how much variation might occur between replicates. The third experiment, during a period of cloudy, warm weather, was started at variable aphid densities, partly to check for density-dependent restrictions on the rate of aphid increase, and partly to compare the predation rate at different prey densities. Each experiment ran until the alfalfa plants were too large for accurate sampling (§ 4), or until an incipient fungal epidemic threatened the aphids. After each experiment, the surviving coccinellids were removed and counted, the cages were sprayed with a short-lived insecticide, and the alfalfa was cut and allowed to grow for two weeks before the next experiment began.

Standard counts, as described in § 4, never revealed more than 25% of the true beetle numbers, even at high temperatures up to 28° and at low aphid densities. The ladybirds spent most of their time in the stubble at the base of the alfalfa. This observation itself can explain the remaining discrepancy: the beetle counts in the field (Fig 8) almost certainly underestimated the actual numbers present. The number of moving beetles (Fig. 10) increased steadily with temperature, but there was no corresponding decrease in the observed number of stationary beetles, which might be expected if all beetles had been visible.

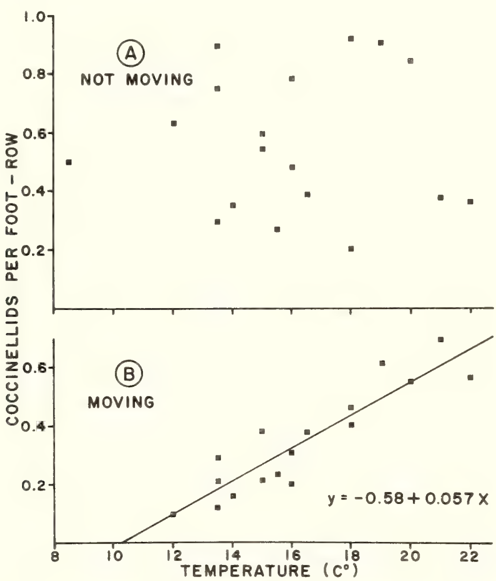


FIGURE 10. Effect of ambient temperature on numbers of C. trifasciata observed moving (10B), and not moving (10A), in field counts (cf. Fig. 7). Each point is the mean of counts from about 60 row-feet.

Analysis of cage experiments

Details of the individual experiments appear in the legends to Figs. 11-13. Each figure shows the means of successive aphid samples, together with the simulation curves generated by the computer. All broken curves refer to control cages without beetles. These curves all show the same rate of aphid increase, or, in other words different sections of the same curve of exponential population increase. They are not exponential at the start of the experiment, because of the initial, non-equilibrium, age-distributions. The relative rate of increase is the same at all aphid densities, but it is far less than would be expected from the aphids' fecundity, estimated in the laboratory. In fact, the broken curves are generated by imposing a 70% reduction in fecundity. We do not know the cause of this discrepancy, which has occurred consistently throughout the whole study, and in later work. Probably it means that fecundity in the field (which cannot be measured directly) is only 30% of that in ideal laboratory conditions. The discrepancy might alternatively be due to predation, at a constant rate of 70% throughout the season, acting on newly-born aphids only (to give the right age-distributions). In the control cages, we had to impose extra mortality of 1.3%/q on aphids of all ages. This 'background' mortality is ascribed to the numerous hunting spiders *Erigone metlakatla* Crosby & Bishop, observed in the cages. There was also a certain amount of parasitization, which we estimated

from counts of mummies (§ 4), and which increased from 0.3%/q in the first experiment to 1.0% in the third.

The 'disturbed' curve in Fig. 11 refers to a cage which contained no coccinellids, but in which the alfalfa was disturbed by hand four times/q, causing some aphids to fall off the plants, as they do when approached by a ladybird. If such aphids do not climb back onto a new plant, the rate of population increase will be reduced. There evidently is some reduction, but not much. The disturbance caused by a beetle is much less than that which we made by hand.

The unbroken curves in Figs. 11-13 were generated by imposing the additional mortality attributed to beetle attack. They assume that the predation occurs independently of the background mortality, i.e. that the overall survival rate is the product of the two separate survival rates. This is a very reasonable assumption, because each coccinellid searches independently of other predators and parasites.

The ladybirds also suffered mortality, mostly from predation by a web-spinning spider, *Enoplognatha ovata* (Clerck). We could not spray to control the spiders, for fear of provoking an outbreak of mites. Therefore, although we introduced known numbers of male and female beetles during each experiment, we do not know the exact numbers alive at any given time. After the end of each experiment, we collected ladybirds from the cages until few, if any, remained. We then computed the survival rate needed to reduce the initial numbers of beetles introduced to the final numbers recovered. The mortality proved to be rather more than 2%/q in all three experiments. The numbers of beetles shown in Figs. 11-13, although accurate at start and finish, thus depend on the assumption of constant survival rates. Our subsequent conclusions are not seriously affected by reasonable deviations from that assumption. At the end of each experiment we took bag samples (§ 4) to convert the numbers of beetles and mummies to a per-terminal basis.

Figs. 11-13 cover a range of field temperatures and aphid densities. We used more than twice as many beetles per cage in cool (Fig. 11), as in warm conditions (Fig. 13). If our understanding of coccinellid predation is reasonably complete, we should be able to apply a single formula (with appropriate temperatures, beetle numbers and initial aphid densities) to all three experiments. It is possible to do so. Every curve in Figs. 11-13 is computed by the same program; and all the parameters in that program, except three, have been estimated from other sources. Two parameters, *viz.* aphid fecundity and background mortality, were dictated by the aphid numbers observed in the control cages. The third parameter is the coefficient which specifies how beetle activity increases with temperature (§ 3). The curves require that beetle activity be, on average, 0.018 times the temperature above 4°C. This is merely an overall parameter chosen to reconcile the unbroken curves with the observations. The computer program, not listed here, is very similar to Appendix 6. We think that the agreement is good, bearing in mind the differences between replicates in Fig. 12. It could easily be improved by minor adjustments. The only serious discrepancy is in Fig. 11, where the computer predicts that increased temperatures, towards the end of the experiment, should have prevented the final increase in aphid density. In fact the weather remained continuously cloudy, which may have depressed beetle activity; we certainly need further information about the effect of weather on beetle activity. Otherwise, the agreement between observation and prediction is acceptable, and so we have a single formula, given in § 3 and used in Appendix 6, which satisfactorily predicts the predation rate over a wide range of temperatures and prey densities.

DISCUSSION

It does not follow that the components of the formula necessarily reproduce the biological details correctly. For example, we have ignored the fact that the hunger curve, used in the field predation model of § 3, refers to *C. undecimpunctata* (Fig. 2A), not to *C. trifasciata.* The hunger curve for *C. trifasciata* (Fig. 2B) was estimated at the end of the investigation, using beetles taken from the field cages. The observations in Fig. 2B were taken at 20°C. The curves in Fig. 2B predict a maximal consumption/q of 5.5 mg/beetle, as compared with the 5.7 mg for *C. undecimpunctata,* used in § 3. Thus the two species agree very closely in this respect, and there is no need to change the formula of § 3. But P.M. Ives informs us that female *C. trifasciata,* kept in the laboratory and fed *ad libitum,* ate only 4.4 mg per q on average. The reason is undoubtedly that given in § 3, that the initial hunger level of 0.88, used in our calculations, is too high for a well-fed beetle. There is therefore some residual ignorance about the voracity of coccinellids in the field, but it is unimportant here: for the computer program generates the same unbroken curves in Figs. 11-13, whatever the maximal consumption (within reasonable limits), provided that the temperature coefficient for beetle activity is altered accordingly. Thus the residual errors in beetle activity cancel the remaining errors in beetle voracity, to give identical predictions of the predation rate.

Whatever the true average level of coccinellid activity may be, it is certainly very low. Watching the predation process in the

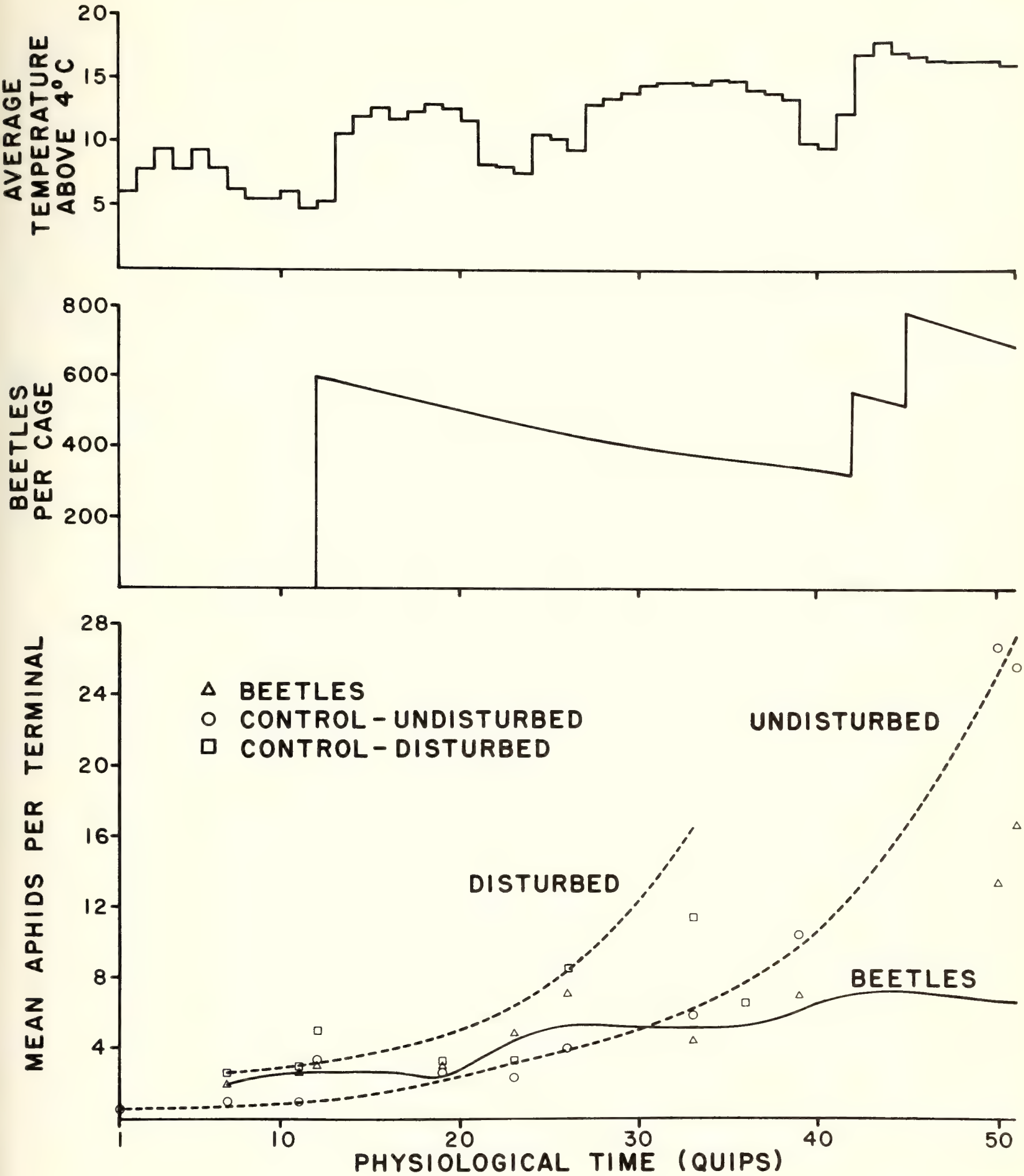


FIGURE 11. First cage experiment. In the lower section the points represent observed sample means but the curves were computed. Each sample in Figs. 11-13 contained about 27 plants, except at the start and end of each experiment, when each sample contained about 36 plants. The curves are largely independent of the observations—see text. The 'undisturbed' curve shows the exponential increase in the absence of ladybird predation. The 'disturbed' curve is computed on the assumption that mechanical disturbance of the plants, causing some aphids to fall off, causes no mortality. The solid line curve predicts the effect of predation by the numbers of beetles shown in the middle section, at the weighted average temperatures shown in the upper section. Compared with Figs. 12 and 13, temperatures were low and the number of beetles needed to show any obvious effect was consequently large. There was a fourth cage containing half the number of beetles shown here, which gave results intermediate between the 'undisturbed' and unbroken curves. To avoid confusion, those results are not shown.

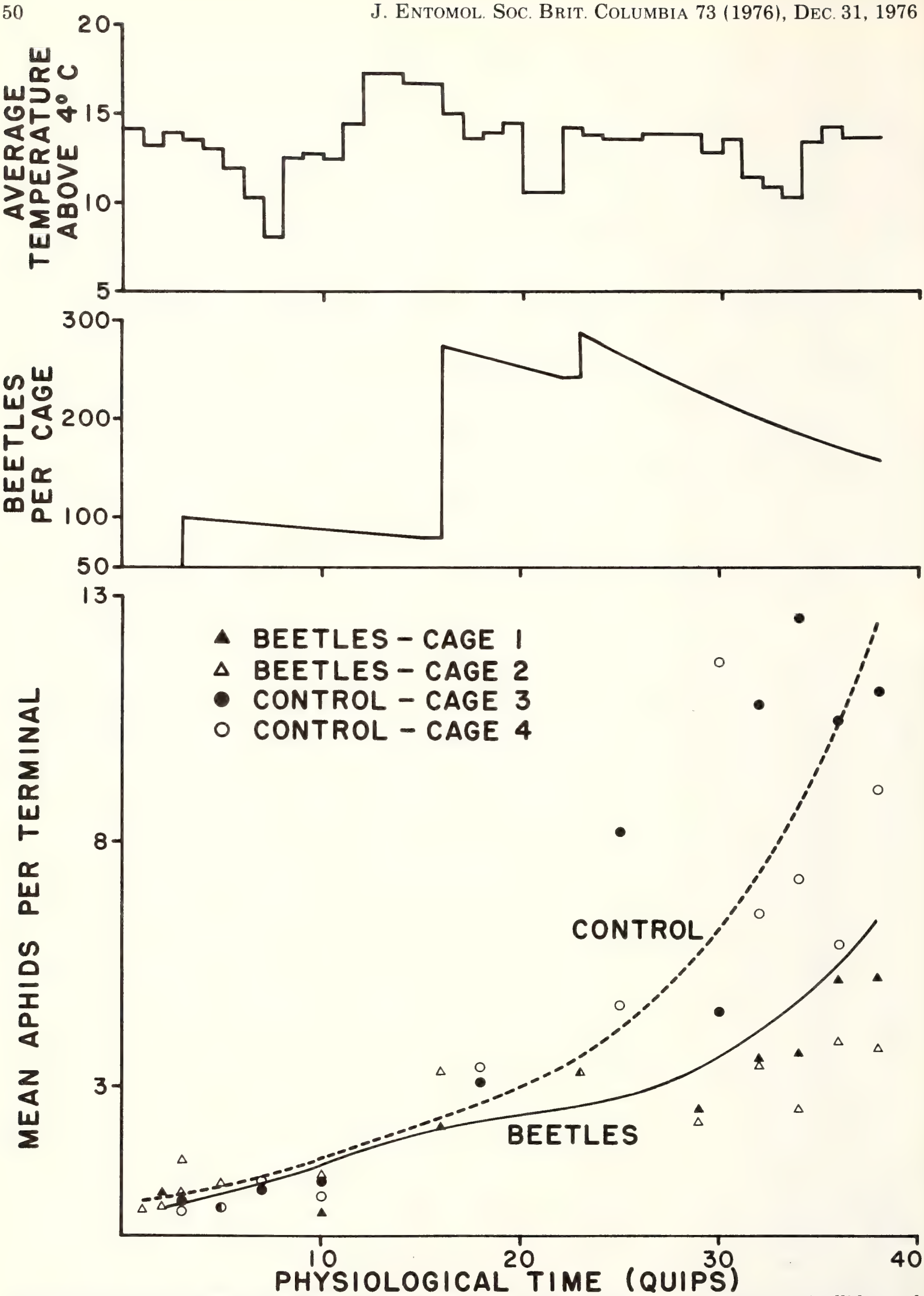


FIGURE 12. Second cage experiment. There were two replicate cages containing coccinellids, and two controls. Only one curve has been computed for each pair of cages. The differences between cages 1 and 2, and between 3 and 4, measure the variation experienced between replicates. These differences must be borne in mind during any examination of Figs. 11-13. Beetle numbers were the same at the start, but declined more in cage 1 than in cage 2, which partly explains the difference in aphid numbers. The number of beetles shown in the middle section is the average for the two cages.

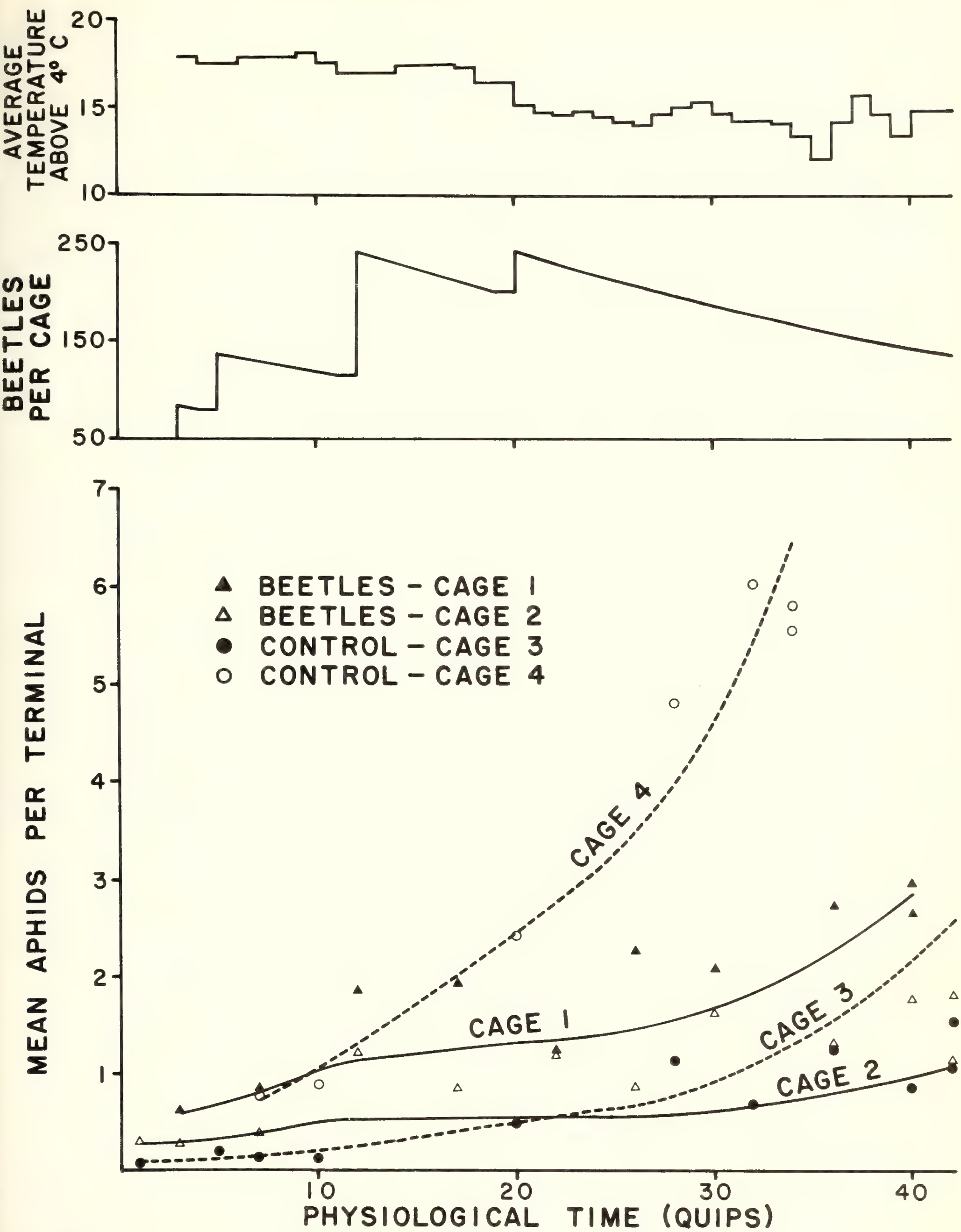


FIGURE 13. Third cage experiment. Different cages were deliberately started at different aphid densities, to examine the effects of aphid density on predation rate and rate of aphid increase. The curves predicted for cages 2 and 3 disagree with the data, but only within the limits of variation revealed in Fig. 12 (see text). The curve for cage 2 remains level from q 11 to q 25, but then begins to rise as temperatures and beetle numbers decline. This illustrates the principle that no equilibrium between aphid and coccinellid numbers can be permanent. Figs. 11-13 have different scales for aphid density. The number of beetles shown in the middle section is the average for the two cages: More survived in cage 1 than in cage 2, and the curves are computed accordingly.

laboratory, we saw a hungry predator anxiously scouring its universe for prey. Watching a population of beetles in a field cage in conditions almost identical with those of the open field, we saw the ladybirds spending a good three-quarters of their time motionless in the stubble. In the laboratory, there was nowhere to hide. The contrast between laboratory and field could not be greater.

The cage experiments give some information about possible interactions between predation and parasitization rates. If parasitized aphids suffer a higher predation rate than unparasitized, there will accordingly be a relative shortage of parasite mummies in the cages containing beetles. No large or consistent difference was seen: such heterogeneity as did occur was restricted to the first experiment, where the parasitization was begun by emerging overwintered adults.

The new formula for predation rate still does not resolve the discrepancy between observation and prediction in Fig. 8. In fact, it makes it worse, because beetle activity is less than we previously supposed (§ 4). We now need four times as many beetles as were actually observed, to produce the decline in aphid numbers shown in Fig. 8, 35-79 q. We can readily believe that, as in the field cages, there were four times as many beetles present as appeared in the samples. Although we have a good estimate of the predation rate, we still have no sure way of sampling beetle numbers in the field. Standard methods using sweep nets, walking counts, or suction machines, are hopelessly inaccurate. Our intensive counts find only a fraction of the numbers actually present, and that fraction must vary with aphid density, temperature, and probably the time of day. The adult coccinellid, at first sight so conspicuous an animal, is in fact very cryptic.

6. CONCLUSIONS

Laboratory v. field studies

The coccinellid-aphid relationship, observed in the field, differs from that in the laboratory in three major respects. The distribution of prey affects the predation rate in the laboratory but not in the field (§ 3). Predators observed in the laboratory were more active than those in the field (§ 5). Temperature has an overriding effect in both laboratory and field—a fact which would not be noticed at constant temperature in the laboratory. Moreover, it has a differential effect on predation rate, and on population dynamics of the prey. This means that predation and population studies on insects *must* include temperature as an essential component, and that studies of predation alone, unlinked to population dynamics can be meretricious. It also means that laboratory studies alone are unreliable, because some vital aspect of the true, i.e. the field relationship may be completely overlooked in the laboratory.

Holling (1966) pioneered the detailed behavioural and physiological approach to the study of predation and discussed the advantages of his approach, over more superficial methods (Holling 1964). Holling's work was so detailed that it could be done only in the laboratory: but the method can be simplified and applied in the field, to predict predation rates which can be reconciled with the population dynamics of the prey. Thus Holling's approach, offering precise predictions over a wide range of contingencies, may be combined with the broader realism of quantitative field studies, as first attempted by Morris (1963). Two major conclusions are therefore that (1) laboratory studies of ecological relationships must not be trusted until verified in the field, and (2) it is in fact possible to make detailed predator-prey studies in the field, to explain the observed impact of predation on the prey population.

Stability

The coccinellid-pea aphid relationship sharply contradicts existing theories on insect predators and prey, and of ecological stability. It permits no steady-state, or equilibrium, between predators and prey. It is true that, for any given aphid density and temperature, there is some number of coccinellids which could keep aphid numbers constant, once the aphid age-distribution had settled to a steady-state: but the ladybirds rarely approach the necessary predator prey ratio, even at high temperatures. Moreover, the relationship would be unstable. Curve C (Fig. 5) shows a monotonic increase of survival rate with aphid density, so that any chance increase in aphid numbers will allow the aphids to gain, and the beetles could not thereafter restore the balance. Conversely, the slightest decrease in aphid numbers would allow the beetles to drive the aphids towards extinction. Moreover, the required number of beetles depends critically on temperature, so that even a slight change in temperature would upset the equilibrium. There is nothing in the coccinellid-aphid functional relationship to prevent either a continual increase in aphid numbers, or a continual decline towards extinction. We have twice observed such a decline in the field (Figs. 1 and 8), which was arrested because the predator left the field when the prey density became very low. The conventional definition of stability (Hassell & May 1973), as a tendency to return towards some steady-state or equilibrium (which need never be actually reached), does not apply here, where the relationship is completely unstable, but extremely resilient (Holling 1973). The

functional response is unstable, and the relationship is stabilized only by the predator's numerical response.

Some technical considerations

To assess the impact of predators on their prey populations, we must compare the numbers of prey actually observed, with the numbers that *would* be observed, in identical field conditions, but in the absence of the predators. This is very difficult to do, especially if the comparison is to cover all conditions normally encountered in the field. The method used here, of dissecting the predation process and tying it into the population dynamics of the prey, is perhaps the only fully reliable method used so far. The chief technical difficulty in the field was not to observe the process of predation but to estimate the density of predators, for which we still have no satisfactory method.

Several theories of predation embody the concept of a predator's, or parasite's, area of search. Our predator is limited at low prey densities, not by its capacity for prey, but by the time available to search for them. This is equivalent to a limited area of search, since the predator cannot search the whole area within the time available. We believe it is better to think in terms of timing, rather than of area of search, partly because it emphasizes the dynamic nature of the predator-prey relationship, and partly because the aphids play hide-and-seek with the beetles. Even if a ladybird could search the whole area, it still would not find all the aphids.

This study offers cold comfort for biological control workers. Since the coccinellid-aphid relationship is unstable and incapable of a steady-state, we cannot expect the coccinellids to keep aphid numbers low for any length of time. Usually the beetles merely slow the increase in aphid numbers. At high temperatures, the beetles can certainly depress aphid numbers (Figs. 1 and 8); but we have seen this happen only during unusually warm periods early in the season; and even then, the beetles quickly left the field in search of other prey. The coccinellids' double temperature requirement, and their mobility, make them ineffective predators, in that they rarely restrict the density of their prey. To use ladybirds as effective and permanent agents for biological control, we must direct their natural behaviour to a quite unnatural end.

7. ACKNOWLEDGEMENTS

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References

Campbell, A., Frazer, B. D., Gilbert, N., Gutierrez, A. P. and M. Mackauer. 1974. Temperature requirements of some aphids and their parasites. **J. Appl. Ecol. 11**, 431-438.

DeBach, P. 1974. Biological control by natural enemies. Cambridge University Press, Cambridge.

Dixon, A. F. G. 1959. An experimental study of the searching behaviour of the predatory coccinellid beetle **Adalia bipunctata** (L.) **J. Anim. Ecol. 28**, 259-281.

Frazer, B. D. and R. van den Bosch. 1973. Biological control of the walnut aphid in California: The interrelationship of the aphid and its parasite. **Environ Ent. 2**,561-568.

Gilbert, N. and A. P. Gutierrez. 1973. A plant-aphid-parasite relationship. **J. Anim. Ecol. 42**, 323-340.

Gilbert, N. and R. D. Hughes. 1971. A model of an aphid population—three adventures. **J. Anim. Ecol. 40**, 525-534.

Gutierrez, A. P., Morgan, D. J. and D. E. Havenstein. 1971. The ecology of **Aphis craccivora** Koch and subterranean clover stunt virus. I. the phenology of aphid populations and the epidemiology of virus in pastures in south-east Australia. **J. Appl. Ecol. 8**, 699-721.

Gutierrez, A. P., Havenstein, D. E., Nix, H. A. and P. A. Moore. 1974a. The ecology of **Aphis craccivora** Koch and subterranean clover stunt virus II. A model of cowpea aphid populations in temperate pastures. **J. Appl. Ecol. 11**, 1-20.

Gutierrez, A. P., Havenstein, D. E., Nix, H. A. and P. A. Moore. 1974b. The ecology of **Aphis craccivora** Koch and subterranean clover stunt virus III. A regional perspective of the phenology and migration of the cowpea aphid. **J. Appl. Ecol. 11**, 21-35.

Hassell, M.P. 1969. A population model for the interaction between **Cyzenis albicans** (Fall.) (Tachinidae) and **Operophtera brumata** (l.) (Geometridae) at Wytham, Berkshire. **J. Anim. Ecol.** 38, 567-576.

Hassell, M. P. and R. M. May. 1973. Stability in insect host-parasite models. **J. Anim. Ecol.** 42, 693-726.

Holling, C. S. 1964. The analysis of complex population processes. **Can. Ent.** 96., 335-347.

Holling, C. S. 1966. The functional response of invertebrate predators to prey density. **Mem. ent. Soc. Can.** No. 48.

Holling, C. S. 1973. Resilience and stability of ecological systems. **Ann. rev. Ecol. & systematics** 4, 1-23.

Huffaker, C. B., Shea, K. P. and S. G. Herman. 1963. Experimental studies on predation: complex dispersion and levels of food in a acarine predator-prey interaction. **Hilgardia** 34, 305-330.

Hughes, R. D. 1963. Population dynamics of the cabbage aphid **Brevicoryne brassicae** (L.) **J. Anim. Ecol.** 32, 393-424.

Hughes, R. D. and N. Gilbert. 1968. A model of an aphid population—a general statement. **J. Anim. Ecol.** 37, 553-563.

Morris, R. R. et al. 1963. The dynamics of epidemic spruce budworm populations. **Mem. ent. Soc. Can.** No. 31.

Morris, R. F. and C. W. Bennett. 1967. Seasonal population trends and extensive census methods for **Hyphantria cunea. Can. Ent.** 99, 9-17.

Wratten, S. D. 1973. The effectiveness of the coccinellid beetle, **Adalia bipunctata** (L.), as a predator of the lime aphid, **Eucallipterus tiliae** L. **J. Anim. Ecol.** 42, 785-802.

Appendices 1, 3, 5 and 6 will be sent upon request to either author.

Appendix 2

Algorithm to compute physiological time in the field

This method was devised by Morris & Bennett (1967), but the algorithm has not been published. Successive daily maximum and minimum field temperatures are stored in an array X. The algorithm fits a sine curve between two successive values of X, and integrates it above the threshold temperature *thresh*. It therefore calculates *two* increments (from min to max and from max to min) for each calendar day. Each increment, B, is calculated in day-degree units if the original temperatures are Fahrenheit, B will be in a day-°F., and similarly for Celsius. The algorithm is applied to successive pairs of values X(I), X(I+1), where I =1, 2, 3 . . .

```
   IF(X(I).LE.X(I+1))GO TO 2
   XMAX=X(I)
   XMIN=X(I+1)
   GO TO 4
 2 XMAX=X(I+1)
   XMIN=X(I)
 4 Y=XMAX+XMIN-2.*THRESH
   IF(XMIN.LT.THRESH)GO TO 6
   B=.25*Y
   GO TO 10
 6 IF(XMAX.GT.THRESH)GO TO 8
   B=0.
   GO TO 10
 8 T=ARCSIN(Y/(XMIN-XMAX))
   B=.125*Y*(1.-.63661977*T)+
     .079577472/(XMAX-XMIN)*COS(T)
10 CONTINUE
```

Appendix 4

Derivation of the expression for survival rate

The problem is to fit a curve to the data points in Fig. 5. At high aphid densities, when the beetles have no trouble in finding aphids, the survival rate s must approach the 'random search' survival rate exp $(-kb/a)$, for the appropriate value of k, which is deduced as follows: In the model, each beetle starts with hunger H=0.88, corresponding to a starvation time of 15 hours. If such a beetle were suddenly presented with all the aphids it needed, it would eat an average of 5.7 mg. of aphids in the first q. This quantity is deduced from the hunger curve when an average beetle eats its fill, and thereafter eats a whole aphid whenever it becomes hungry enough to do so. Therefore, the beetle will eat 5.7/AWT aphids, each of weight AWT (Table 1), so that the appropriate value of k is 5.7/AWT. Curve A (Fig. 5) is the random search survival s $=\exp(-5.7b/(\text{AWT}\text{-}xa))$, or for mathematical convenience

$$-\log s = 5.7\, b / (\text{AWT} \times a)$$

This defines the required curve at the top end of the scale in Fig. 5. We shall now derive a theoretical value for -log s at the other end of the scale, when aphid density is very low. In the model, a beetle takes 51.3 seconds to visit one plant, provided that no aphid is found and eaten. At 18.5°C, 1 q lasts 40,000 seconds, in which time each beetle can visit 780 plants. Since there are b beetles per plant, each plant will receive an average of m=780 b visits/q. Any given plant will actually be visited r times, where r follows the Poisson distribution with mean, i.e. the probability of exactly r visits

is $e^{-m}m^r/r!$. We shall suppose that the aphid density is almost zero, so that most plants carry no aphids, but a few plants have a single aphid. In such circumstances, the beetles will be completely hungry (H=1). The probability of an aphid being eaten, when a beetle visits its plant, is PE, estimated from field observation to be 0.0205, which is the value of PE used in the field predation model of Appendix 3 to compute the data points of Fig. 5. The probability that one aphid survives one visit by the beetle is therefore (1-0.0205), and so the probability that it survives r successive visits is $(1\text{-}0.0205)^r$. The average survival rate s will therefore be the average value of this expression for all values of r, i.e. $\sum_r (1\text{-}0.0205)^r e^{-m} m^r/r!$, which reduces to s=exp (-0.0205 m). Since m=780 b, it follows that, at near-zero aphid density,

$$-\log s = 0.0205 \times 780\, b. \qquad (2)$$

The required survival curve must therefore agree with expression (1) at high aphid densities, and with (2) when the aphid density a approaches zero. There are many such curves, but an obvious one (mathematically speaking) to try is:

$$-\log s = 5.7b\,[1 - \exp(-ka)]/(\text{AWT} \times a) \qquad (3).$$

This expression approaches (1) for large values of a, and it also satisfies the requirement stated in §3, that if the beetle density b is doubled, the survival rate s is squared. Expression (3) agrees with (2) as a tends to zero if the appropriate value, namely

$$0.0205 \times 780 \times \text{AWT} / 5.7 \qquad (4).$$

is chosen for the parameter k. When the value of AWT for second-instar aphids is substituted in (3), we get curve B of Fig. 5.

It is obvious from Fig. 5 that curve B still does not fit the data points very well. Although there are many other curves which satisfy the requirements of (1) and (2), it is unlikely that any equally simple formula will give a better fit than curve B. Rather than try one formula after another, it is better to tailor (3) to fit the data points. In expression (3), the term (-5.7b/AWT x a) represents the random search of expression (1), while the term [1-exp(-ka)] reflects the fact that, at low aphid densities, the beetle has insufficient time to catch all the aphids it wants. Indeed, when expression (4) is substituted for k, the value of ka turns out to be the number of aphids which a beetle can expect to catch in a given time, divided by the number of aphids required to keep the beetle satiated during that time. Mathematically speaking, we could alter the terms for either random search or insufficient time; but since curve B gives a poor fit only at small aphid densities, it makes better biological sense to modify [1 - exp(ka)]. The value of k is evidently not constant, but must vary with the aphid density a. Its value ko, when a=O, must still be given by (4). From each survival rate computed by the predation model (Fig. 5), we deduce the appropriate value of k in (3). Fig. 14 shows the values of k/ko for varying aphid densities. When a 'greater than' 4, the value of k/ko is of no concern because the insufficient time factor (1 -exp(-ka)) then has little effect on the survival rate.

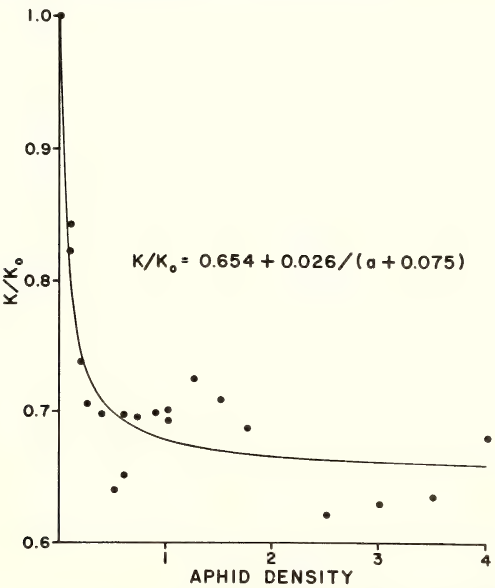

FIGURE 14. Values of k/ko deduced from Fig. 5 and the curvilinear regression, weighted according to the accuracy of each point.

In Fig. 14, a rectangular hyperbola has been fitted to the values of k/ko by non-linear regression, weighted according to the accuracy of each point, giving the formula $k/ko = 0.654 + 0.026/(a + 0.75)$. This formula contains two independent empirical parameters, because k/ko must equal unity when $a = 0$. We call k/ko the 'hunger correction', for the following reason: the curve for k/ko remains unchanged when we alter PE, PL, TS, or the instar of the aphids concerned. Such changes (with the exception of PL) will, of course, alter the survival rate s directly from the formula for ko. However, an acceleration of the beetle's digestion (i.e. of the rate at which its hunger H increases with time) does increase the value of k/ko somewhat, whenever the aphid density, a, exceeds one per plant, but has little effect at lower densities, when the beetle is continuously very hungry. For example, according to the predation model, the beetle's average relative hunger H is 0.64 at aphid density $a = 1$, but 0.91 at $a = 0.1$. It appears, then, that the shape of the k/ko curve in Fig. 14 is largely due to the fact that, the fewer aphids there are, the hungrier the beetle remains, and the more anxiously it searches. It must be remembered that changes in hunger level affect not only k/ko, but the random search term as well.

We thus end up with expression (3), but with

$$k = 0.0205 \times 780 \times \mathrm{AWT}[0.654 + 0.026/(a + 0.075)]/5.7 \qquad (5).$$

We then get curve C in Fig. 5, which fits the computed data points well. Finally we must reconsider the value of PE, since it varies according to the aphid instar. In face, PE equals some constant times FACTE (Table 2). We recorded the instar of every aphid which we saw captured in the field, and the average value of FACTE for those aphids is 1.07. To reproduce the estimated overall value of PE (0.0205), we write PE=0.019 x FACTE, since 0.019 x 1.07=0.0205. The figure 0.0205 in (5) must therefore be replaced by 0.019 x FACTE, and we then have the formula for survival rate used in Appendix 5. This means, incidentally, that the estimated overall value 0.0205 should not be used in Appendix 3, since FACTE=1.28 for second-instar aphids (Table 2), giving a corresponding PE=0.019 x 1.28=0.024. This error does not affect the analysis in this Appendix, since the k/ko curve is unaffected by changes in PE.

THE APHIDS (HOMOPTERA: APHIDIDAE) OF BRITISH COLUMBIA 4. FURTHER ADDITIONS AND CORRECTIONS[1]

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ABSTRACT

Twenty-five species of aphids are added to the taxonomic list of the aphids of British Columbia. New host records, a few corrections, and some name changes are also included.

INTRODUCTION

Two previous lists of the aphids of British Columbia recorded 261 species collected from 294 hosts or in traps (Forbes, Frazer, and MacCarthy 1973; Forbes, Frazer and Chan 1974).

The present list adds 25 species of aphids (indicated with an asterisk in the list) and 213 aphid-host plant associations to the previous lists. One hundred and twenty-nine of the new aphid-host plant associations are plant species not in the previous lists. The additions bring the number of known aphid species in British Columbia to 286. Aphids have now been collected from 423 different host plants.

The present paper includes a few corrections to the previous lists and some name changes in conformity with current usage in aphid taxonomy. The aphids are arranged alphabetically by species. The location of each collection site can be determined from Table 1 or from the tables of localities in the previous papers.

The complete data for all collections have now been computerized, so that up-to-date aphid or host lists are easily available. The computer programming is described in detail elsewhere in this Journal (Raworth, and Frazer 1976).

[1]Contribution No. 387, Research Station, 6660 N. W. Marine Drive, Vancouver, British Columbia, V6T 1X2.

LIST OF SPECIES

ABIETINUM (Walker), ELATOBIUM
Picea sp: Vancouver, May 3/74, May 7/75.

AEGOPODII (Scopoli), CAVARIELLA
Petroselinum crispum: Vancouver, Apr. 29/75.

ALBIPES Richards, THELAXES
Quercus prinus: Vancouver (UBC), Jun 6/75, Jun 11/75.

ALNI (DeGeer), PTEROCALLIS
Alnus rubra: Vancouver, Sep 26,75.

ALNIFOLIAE ALNIFOLIAE (Williams), PROCIPHILUS Previously listed as PROCIPHILUS ALNIFOLIAE Williams.
Amelanchier canadensis: Vancouver (UBC), Jun 11/75.

ANNULATUS (Hartig), TUBERCULOIDES
Quercus garryana: Vancouver (UBC), Jun 11/75.
Quercus robur: Vancouver, Sep 26/75; Vancouver (UBC), Jun 12/74.
Quercus robur var *fastigiata:* Vancouver (UBC), Jun 18/75.
Quercus sp: Vancouver, Jun 2/73.

ASCALONICUS Doncaster, MYZUS
Arctostaphylos uva-ursi: Vanncouver (UBC), May 5/75.
Fragaria Sp: Vancouver (UBC), May 15/74.
Lactuca sp: Vancouver, Apr 5/58.
Ranunculus occidentalis: Vancouver, May 20/75.
Rheum rhaponticum: Vancouver, May 20/75.
Viola sp: North Vancouver, May 25/75.

TABLE 1. Localities where aphids were collected, with airline distances from reference points.

Locality	Reference Point	Dir.	Distance km	Distance mi
Bridesville	Kelowna	S	94	59
Delta	Vancouver	S	24	15
Lac La Hache	Williams Lake	SE	58	36
Laidlaw	Vancouver	E	104	65
Robson	Creston	NW	93	58
Salmon Arm	Kamloops	E	72	45
West Vancouver	Vancouver	W	13	8

*AUREUS Richards, BETULAPHIS
Betula sp: Terrace, Jul 12/60 (Richards 1961a).

AVENAE (Fabricius), MACROSIPHUM
Avena sativa: Agassiz, Jul 28/69.
Juncus articulatus: Vancouver (UBC), Aug 7/74.
Juncus bufonius: Vancouver (UBC), Aug 7/74.
Scirpus validus: Vancouver (UBC), Aug 9/74.
Triglochin maritimum: Vancouver (UBC), Aug 9/74.
Zea mays: Agassiz, Jul 28/69.

BAKERI (Cowen), ROEPKEA
Crataegus douglasii: Vancouver (UBC) Jun 5/75.
Prunus avium: Summerland, Oct 25/74.
Prunus domestica: Summerland, Oct 25/74.

BERBERIDIS (Kaltenbach), LIOSOMAPHIS
Berberis aquifolium: Vancouver, May 15/73; Vancouver (UBC), Jul 8/74.
Berberis hybrido-gagnepaini: Vancouver (UBC), Jun 19/75.

BICOLOR BICOLOR (Oestlund), PTEROCOMMA
Populus nigra var *italica:* Vancouver (UBC), Apr 24/74, Apr 26/74, Apr 30/74, May 9/73.
Populus sp: Vancouver (UBC), May 21/73.
Populus trichocarpa: Vancouver (UBC), May 21/73.
Salix sp: North Vancouver, May 20/73.

BURSARIUS (Linnaeus), PEMPHIGUS
Populs nigra var *italica:* Vancouver (UBC), Jun 28/73.

CALIFORNICUM (Clarke), MACROSIPHUM
Salix scouleriana: Vancouver (UBC), Jun 25/74.
Salix sp: Vancouver (UBC), Jun 8/73.

*CALLUNAE Theobald, APHIS
Calluna vulgaris: Vancouver (UBC), Jul 18/74, Jul 19/74.

CARAGANAE (Cholodkovsky), ACYRTHOSIPHON
Caragana arborescens: Vancouver (UBC), Aug 14/75.

CARDUI (Linnaeus), BRACHYCAUDUS
Prunus domestica: Summerland, Oct 25/74.

CASTANICOLA Baker, MYZOCALLIS
Castanea dentata: Vancouver (UBC), Sep 4/75.

CERASI (Fabricius), MYZUS
Prunus avium: Summerland, Oct. 25/74.
Prunus cerasus: Vancouver (CDA), Apr 18/75 (In Rearing Room).
Prunus emarginata: Creston, May 30/75, Jun 28/75; Robson, Jun 29/75.
Prunus serrulata var *shirofugen:* Vancouver, May 13/75.
Prunus sp: Creston, Jun 28/75; Summerland, Jun 3/75.

CERASIFOLIAE (Fitch), RHOPALOSIPHUM
Prunus virginiana: Summerland, May 28/75, Jun 19/75.
Prunus viginiana var *demissa:* Bridesville, Jun 4/75: Robson, Jun 29/75.

CIRCUMFLEXUS (Buckton), AULACORTHUM
Campanula persicifolia: Vancouver, Aug 19/75.
Oxalis corniculata: Vancouver, Jul 23/75, Aug 19/75.

CIRSII (Linnaeus), DACTYNOTUS
Cirsium arvense: Ladner, Jul 17/74.

CLAVICORNIS Richards, AULACORTHUM
Rosa sp: Williams Lake, Jun 15/56.

CORNI (Fabricius), ANOECIA
Cornus obliqua: Vancouver (UBC), Oct 24/75.

CORNIELLA Hille Ris Lambers, APHIS
Cornus 'Eddie's White Wonder': Vancouver (UBC), Sep 9/75.
Cornus florida: Vancouver (UBC), Sep 9/75.
Cornus florida var *pluribracteata:* Vancouver (UBC), Sep 9/75.
Cornus kousa: Vancouver (UBC), Sep 9/75.
Cornus mas: Vancouver (UBC), Sep 11/75.
Cornus obliqua: Vancouver (UBC), Sep 11/75.
Cornus racemosa: Vancouver (UBC), Sep 9/75.

CORYLI (Goeze), MYZOCALLIS
Corylus cornuta: Vancouver (UBC), Aug 27/74, Oct 2/75.

*COWENI (Cockerell), TAMALIA
Arctostaphylos uva-ursi: Vancouver (UBC), Sep 12/75.

CRACCIVORA Koch, APHIS
Holodiscus discolor: Brentwood, Jul 5/59.

CYPERI (Walker), TRICHOCALLIS
Carex sitchensis: Vancouver (UBC), Aug 9/74.

DIRHODUM (Walker), ACYRTHOSIPHON
Crataegus oxyacantha 'Paul's Scarlet': Vancouver (UBC), Jun 5/75.

DORSATUM Richards, AULACORTHUM
Gaultheria shallon: Vancouver (UBC), Sep 2/75.

ELAEAGNI (Del Guercio), CAPITOPHORUS
Previously listed as ELAEGNI (del Guercio) due to a typographical error.

*ENIGMAE Hottes & Frison, RHOPALOSIPHUM
Typha latifolia: Vancouver (UBC), Aug 9/74.

*EPILOBII Kaltenbach, APHIS
Epilobium watsonii: Vancouver, Jun 11/73.

ERIOPHORI (Walker), CERURAPHIS
Carex sitchensis: Vancouver (UBC), Aug 9/74.
Scirpus microcarpus: Vancouver (UBC), Aug 9/74.
Viburnum opulus: Vancouver, Apr 22/73.

EUPHORBIAE (Thomas), MACROSIPHUM
Chaenomeles japonica: Vancouver, Jun 13/75.
Cornus stolonifera: Vancouver (UBC), Jul 15/75, Aug 5/75, Aug 27/74.
Dahlia sp: Vancouver, Aug 1/74.
Deutzia gracilis: Vancouver (UBC), Jun 19/75.
Deutzia x *rosea* var *carminea:* Vancouver (UBC), Jun 18/75.
Dicentra formosa: Vancouver (UBC), Jun 10/74.
Escallonia x *edinensis:* Vancouver (UBC), Sep 4/75.
Forsythia sp: Vancouver (UBC), Jun 27/75.
Fragaria sp: Victoria, May 30/57.
Fuchsia hybrida: Vancouver, Aug 27/75.
Gynura aurantiaca: Richmond, Nov 4/75.
Halesia carolina: Vancouver (UBC), Jun 26/75, Jul 22/75.
Hypochaeris radicata: Vancouver (UBC), Jun 13/75.
Ilex aquifolium var *aureo-marginata:* Vancouver (UBC), Jun 18/75.
Iris kaempferi: Vancouver (UBC), Aug 28/74.
Lapsana communis: Vancouver, Jun 13/75.
Liriodendron tulipifera: Vancouver (UBC), Jun 9/75, Aug 14/75.
Montia sibirica: Vancouver (UBC), Jun 13/75.
Philadelphus lewisii: Vancouver (UBC), Jul 15/75.
Philadelphus lewisii var *gordonianus:* Vancouver, Apr 20/73; Vancouver (UBC), Jun 22/59, Aug 8/59.
Philadelphus x *virginalis:* Vancouver (UBC), May 16/75, Jun 17/75, Jun 18/75, Jun 26/75, Jun 27/75.
Rosa sp: Vancouver, May 16/73, May 16/74.
Salix sp: Vancouver, Jun 13/73.
Spiraea douglasii: Vancouver (UBC), Jun 25/74, Jul 15/75.
Verbena x *hybrida:* Trout Creek, Sep 3/65.
Vinca minor: Vancouver (UBC), Jun 19/75.

FABAE Scopoli, APHIS
Amelanchier canadensis: Vancouver (UBC), Jun 11/75.
Callistephus chinensis: Vancouver (CDA), Aug 7/75 (In Greenhouse).
Chenopodium album: Vancouver (UBC), Aug 11/75.
Cuscuta subinclusa: Vancouver (CDA), Aug 7/75 (In Greenhouse).
Deutzia gracilis: Vancouver (UBC), Jun 19/75.
Euonymus alatus: Vancouver (UBC), Sep 4/75.
Euonymus europaea: Vancouver (UBC), May 23/75, Sept 9/75, Sep 22/75.
Euonymus latifolius: Vancouver (UBC), Sep 9/75.
Fatsia japonica: Vancouver, Jul 13/75.
Ficus carica: Vancouver (UBC), Jun 23/75.
Hedera helix: North Vancouver, May 16/73.
Liriodendron tulipifera: Vancouver (UBC), Aug 14/75.
Matricaria matricarioides: Vancouver (UBC), Jul 21/75.
Philadelphus lewisii var *gordonianus:* Vancouver, Apr 20/73.
Philadelphus sp: Vancouver, Jun 29/71.
Philadelphus x *virginalis:* Vancouver (UBC), May 16/75, Jun 18/75.
Sassafras albidum: Vancouver (UBC), Sep 9/75.
Viburnum trilobum: Vancouver (UBC), Jul 3/75, Sep 3/75.

FAGI (Linnaeus), PHYLLAPHIS
Fagus sylvatica var *purpurea:* Vancouver, May 14/73.

FARINOSA Gmelin, APHIS
Salix sp: West Vancouver, May 25/73.

FIMBRIATA Richards, FIMBRIAPHIS
Arctostaphylos uva-ursi: Vancouver (UBC), Jun 2/75.
Fragaria sp: Agassiz, May 15/75; Lulu Island, May 23/57.

FRAGAEFOLII (Cockerell), CHAETOSIPHON
Fragaria sp: Lulu Island, Jul 17/57; Vancouver, Apr 24/59; Vancouver (UBC), May 15/74.
Rosa sp: Summerland, Jun 19/75.

FRAGARIAE (Walker), MACROSIPHUM
Juncus bufonius: Vancouver (UBC), Aug 7/74.
Rubus discolor: Vancouver (UBC), Jun 12/74.
Scirpus validus: Vancouver (UBC), Aug 9/74.

*GALEOPSIDIS (Kaltenbach) CRYPTOMYZUS
Ribes laxiflorum: Vancouver, Aug 3/60.

*GENTNERI (Mason), FIMBRIAPHIS
Amelanchier laevis: Vancouver (UBC), Jun 5/75.
Crataegus douglasii: Vancouver (UBC), Jun 5/75.
Mespilus germanica: Vancouver (UBC), Apr 28/75, Jun 11/75.

*GLYCERIAE (Kaltenbach), SIPHA
Agrostis alba var *palustris: Vancouver (UBC), Jul 23/74.*

GRAVICORNIS (Patch), PARATHECABIUS
Previously listed as THECABIUS GRAVICORNIS (Patch).

HEDERAE (Kaltenbach), APHIS
Previously listed as APHIS PSEUDOHEDERAE Theobald.
Hedera helix: North Vancouver, May 16/73.

HELICHRYSI (Kaltenbach), BRACHYCAUDUS
Chaenomeles japonica: Vancouver, Jun 13/75.
Philadelphus sp: Vancouver, Jun 8/59.
Philadelphus x *virginalis:* Vancouver (UBC), Jun 20/75.

Prunus domestica: Robson, May 30/75; Summerland, Oct 25/74.
Prunus sp: Surrey, May 20/73.
Verbena x *hybrida:* Trout Creek, Sep 3/65.

HERACLELLA Davis, APHIS
Heracleum lanatum: Vancouver (UBC), Aug 7/75.

HIPPOPHAES (Walker) CAPITOPHORUS
Polygonum lapathifolium: Vancouver (UBC), Aug 26/74.
Polygonum persicaria: Pemberton, Aug 25/75.

*HUMBOLDTI (Essig), SITOMYZUS
Physocarpus malvaceus: Vancouver (UBC), May 28/75.

*HYDRANGEAE (Matsumura), RHOPALOSIPHONINUS
Deutzia gracilis: Vancouver (UBC), Jun 19/75.

JUGLANDICOLA (Kaltenbach), CHROMAPHIS
Juglans sp: Vancouver, May 29/73.

*KNOWLTONI Robinson, MYZODIUM
Callitriche stagnalis: Vancouver (UBC), Aug 26/74.

LACTUCAE (Linnaeus), *HYPEROMYZUS*
Ribes laxiflorum: Burnaby, Jun 6/75.

LACTUCAE (Passerini), ACYRTHOSIPHON
Lactuca sp: Penticton, Jul 27/67.

LAMBERSI MacGillivray, MASONAPHIS
Gaultheria shallon: Vancouver (UBC), Jun 17/75.
Ilex altaclarensis: Vancouver (UBC), Jun 18/75.
Ilex aquifolium: Vancouver (UBC), Jun 18/75.
Ilex aquifolium var *aureo-marginata:* Vancouver (UBC), Jun 18/75.
Rhododendron 'Directeur Moerlands': Vancouver (UBC), Jun 9/75.
Rhododendron 'Glacier'': Vancouver (UBC), Sep 3/75.
Rhododendron luteum: Vancouver (UBC), Jun 6/75, Jun 9/75.
Rhododendron 'Princess Elizabeth': Vancouver (UBC), Jun 6/75, Jun 9/75.
Rhododendron sp: Burnaby, Jun 9/75: Vancouver, Jun 6/75; Vancouver (UBC), Jun 16/75, Jun 17/75.

LANIGERUM (Hausmann), ERIOSOMA
Pyrus fusca: Delta, May 7/73.

LONGICAUDA Richards, ASPIDAPHIS
Spiraea douglasii: Vancouver (UBC), Jul 15/75.

LYTHRI (Schrank), MYZUS
Prunus domestica: Vancouver, Jun 2/73.

MACROSIPHUM (Wilson), ACYRTHOSIPHON
Amelanchier alnifolia: Summerland, May 28/75.
Amelanchier canadensis: Vancouver (UBC), Jun 11/75.
Amelanchier laevis: Vancouver (UBC), Jun 5/75.

*MAGNA Hille Ris Lambers, MASONAPHIS
Composites: Lac La Hache, Jul 6/66 (Hille Ris Lambers 1974).

*MANITOBENSIS Robinson, MACROSIPHUM
Cornus stolonifera: Vancouver (UBC), Jun 12/74.

MAXIMA (Mason), MASONAPHIS
Rubus parviflorus: Vancouver (UBC), Apr 3/74, Apr 18/74, Apr 22/74, Jun 18/74, Aug 27/74.

*MODESTUM (Hottes), MYZODIUM
Pogonatum urnigerum: Vancouver (UBC), Aug 26/74.
Polytrichum commune: Vancouver (UBC), Aug 6/74, Aug 7/74, Aug 14/74.
Polytrichum juniperinum: Vancouver (UBC), Mar 6/75, Jul 3/74, Jul 8/74, Jul 16/74, Jul 23/74, Aug 2/74, Aug 7/74, Aug 9/74.

MORRISONI (Swain), MASONAPHIS
Chamaecyparis pisifera: Vancouver (UBC), Aug 15/74.
Chamaecyparis pisifera 'Boulevard': Vancouver (UBC), Jul 30/74.
Chamaecyparis pisifera 'Filifera': Vancouver (UBC), Aug 15/74.
Chamaecyparis pisifera 'Plumosa': Vancouver (UBC), Jul 30/74, Aug 15/74, Aug 27/75.
Chamaecyparis pisifera 'Squarrosa': Vancouver (UBC), Jul 30/74.
Cupressocyparis leylandii: Vancouver (UBC), Aug 15/74.
Juniperus chinensis 'Pfitzeriana': Vancouver (UBC), Aug 15/74.
Sequoiadendron giganteum: Vancouver (UBC), Sep 4/75, Sep 11/75.
Thuja plicata: Vancouver (UBC), Aug 29/74.

NEOMEXICANA (Cockerell), APHIS
Ribes laxiflorum: Agassiz, May 11/59.
Ribes sanguineum: Vancouver (UBC), May 16/75.

NERVATA (Gillette), WAHLGRENIELLA
Arbutus menziesii: Vancouver (UBC), Apr 7/75, Apr 28/75.

NYMPHAEAE (Linnaeus), RHOPALOSIPHUM
Alisma plantago-aquatica: Vancouver (UBC), Aug 28/74.
Elodea canadensis: Vancouver, Sep 22/74.
Prunus avium: Summerland, Oct 25/74.
Prunus domestica: Summerland, Oct 25/74.
Prunus persica: Summerland, Oct 25/74.
Prunus sp: Surrey, May 20/73.
Saururus cernuus: Vancouver (UBC), Aug 28/74.

OCCIDENTALIS (Davidson), CINARA
Abies siberica: Vancouver (UBC), Jul 10/75.

ORNATUS Laing, MYZUS
Abelia 'Edward Goucher': Vancouver (UBC), Jun 24/75, Oct 24/75.
Campanula persicifolia: Vancouver, Jul 15/75, Aug 19/75.
Deutzia x *rosea* var *carminea:* Vancouver (UBC), Jun 18/75.
Forsythia x *intermedia:* Vancouver (UBC), Jun 18/75.
Gynura aurantiaca: Richmond, Nov 5/75.
Lactuca sp: Vancouver, Apr 5/58.
Lapsana communis: Vancouver, Jun 13/75.
Mentha spicata: Vancouver, Jul 23/75.
Oxalis corniculata: Vancouver, Jul 23/75.
Philadelphus lewisii var *gordonianus:* Vancouver (UBC), May 22/58.
Philadelphus x *virginalis:* Vancouver (UBC), Jun 18/75.
Primula alpicola ssp *luna:* Vancouver (UBC), Sep 12/75.
Ranunculus occidentalis: Vancouver, May 20/75.
Rheum rhaponticum: Vancouver, May 20/75.
Trifolium pratense: Vancouver, Sep 26/75.
Weigela 'Eva Rathke': Vancouver (UBC), Jul 3/75, Sep 3/75.

OSMARONIAE (Wilson), MACROSIPHUM
Osmaronia cerasiformis: Vancouver (UBC), Apr 30/75, Aug 29/74.

PADI (Linnaeus), RHOPALOSIPHUM
Prunus virginiana: Summerland, May 28/75.

*PALUSTRIS (Theobald), EUSCHIZAPHIS
Juncus articulatus: Vancouver (UBC), Aug 6/74, Aug 7/74.
Juncus tenuis: Vancouver (UBC), Aug 6/74.

PARVIFLORI Hill, AMPHOROPHORA
Rubus discolor: Vancouver (UBC), Jun 12/74, Jun 25/74.

PASTINACAE (Linnaeus), CAVARIELLA
Heracleum lanatum: Vancouver, May 24/73; Vancouver (UBC), Aug 7/75.
Salix lasiandra: Vancouver, Sep 26/75.
Salix sp: Vancouver, Jun 5/73.

PERSICAE (Sulzer), MYZUS
Callistephus chinensis: Vancouver (CDA), Nov 3/75 (In Greenhouse).
Capsicum sp: Chilliwack, Aug 27/74.
Convolvulus sepium: Vancouver, May 15/75.
Daucus carota: Vancouver (CDA), May 23/74 (In Greenhouse).
Epilobium watsonii: Vancouver (UBC), Aug 18/75.
Philadelphus x *virginalis:* Vancouver (UBC), Jul 22/75.
Pisum sativum: Vancouver (CDA), Nov 17/75 (In Greenhouse).
Plantago major: Vancouver (UBC), Sep 11/74.
Portulaca oleracea: Vancouver (UBC), Sep 11/74.
Prunus persica: Summerland, Oct 25/74.
Vicia faba: Agassiz, Jul/65.

*PILICORNIS (Hartig), CINARA
In flight: Vancouver (UBC), Jun 11/75.
Tsuga heterophylla: Vancouver, Jul 14/75.

PINEA (Mordvilko), CINARA
Pinus nigra: Vancouver (UBC), Jun 23/75.
Pinus sylvestris: Vancouver (UBC), Sep 4/75.

PINETI (Fabricius), SCHIZOLACHNUS
Pinus sylvestris: Vancouver (UBC), Sep 4/75.

*PISUM SPARTII (Koch), ACYRTHOSIPHON
Cytisus scoparius: Vancouver (UBC), Aug 29/74.

PLANTAGINEA (Passerini), DYSAPHIS
Malus sp: Vancouver (UBC), Jun 13/75.

POMI DeGeer, APHIS
Amelanchier canadensis: Vancouver (UBC), Jun 11/75.
Cotoneaster bullata: Vancouver (UBC), Jun 20/75.
Cotoneaster dammeri: Vancouver (UBC), Jun 5/75.
Cotoneaster horizontalis: Vancouver (UBC), Jun 5/75.
Cotoneaster salicifolia 'Repens': Vancouver (UBC), Jun 5/75.
Crataegus douglasii: Vancouver (UBC), Jun 5/75.
Malus ionensis: Vancouver (UBC), Jun 17/75.
Pyracantha crenulata 'Flava': Vancouver (UBC), Sep 11/75.
Sorbus aucuparia: Vancouver (UBC), Jun 18/75.

POPULIMONILIS (Riley), PARATHECABIUS
Previously listed as THECABIUS POPULIMONILIS (Riley).

POPULIVENAE Fitch, PEMPHIGUS
Rumex acetosella: Richmond, Oct 6/75.

*PRAETERITA Walker, APHIS
Epilobium angustifolium: Lulu Island, Jul 14/70.

*PRUNI Wilson & Davis, ASIPHONAPHIS
Prunus virginiana: Summerland, May 28/75.

PRUNI (Geoffroy), HYALOPTERUS
Prunus avium: Summerland, Oct 25/74.
Prunus domestica: Summerland, Oct 25/74.
Typha latifolia: Salmon Arm, Aug 18/74; Vancouver (UBC), Aug 9/74.

*PSEUDOMORRISONI MacGillivray, MASONAPHIS
Juniperus squamata 'Meyeri': Vancouver (UBC), Sep 11/75.

PSEUDOTAXIFOLIAE Palmer, CINARA
Moericke yellow pan water trap: Chilliwack, Aug 2/67.

*PUNCTATA (Monell), MYZOCALLIS
Quercus macrocarpa: Vancouver (UBC), Jul 10/75.
Quercus prinus: Vancouver (UBC), Jun 11/75.

PUNCTIPENNIS Zetterstedt, EUCERAPHIS
Betula papyrifera var *commutata:* Vancouver (UBC), Apr 18/74.

RHAMNI Clarke, MACROSIPHUM
Rhamnus purshiana: Vancouver (UBC), Nov 4/75.

ROSAE (Linnaeus), MACROSIPHUM
Ilex altaclarensis: Vancouver (UBC), Jun 18/75.
Ilex glabra: Vancouver (UBC), Jun 19/75.
Ilex integra: Burnaby, Jun 9/75.

RUSSELLAE Hille Ris Lambers, DACTYNOTUS
Anaphalis margaritacea: Vancouver (UBC), Sep 12/75, Sep 23/75.

SAMBUCIFOLIAE Fitch, APHIS
Sambucus racemosa var *arborescens:* Vancouver (UBC), Apr 19/75, Apr 30/75, Aug 27/74.

SANGUICEPS Richards, PTEROCOMMA
Salix scouleriana: Vancouver (UBC), Apr 18/74, Apr 30/74, May 10/74.
Salix sp: Vancouver (UBC), Oct 23/48.

SCABROSUM Richards, AULACORTHUM
Rubus spectabilis: Vancouver (UBC), Jun 25/74.

SCLEROSA Richards, ROEPKEA
Crataegus douglasii: Duncan, Aug 4/65 (Richards 1969).
Lathyrus nevadensis ssp *lanceolatus:* Victoria, Aug 5/65 (Richards 1969).

SENSORIATA (Gillette & Bragg), ROEPKEA
Previously listed as SENSORIATA (Gillette & Palmer) due to a typographical error.

SIPHUNCULATA Richards, PLACOAPHIS
In flight: Vancouver (UBC), Sep 23/75.
Rosa sp: Creston, Jun/55 (Richards 1961b).

SOLANI (Kaltenbach), AULACORTHUM
Aucuba japonica: Vancouver, Jun 4/74.
Clematis 'Nelly Moser': North Vancouver, May 20/74.
Digitalis purpurea: Vancouver, Sep 26/75.
Heracleum lanatum: Vancouver (UBC), Jun 9/75.
Lapsana communis: Vancouver, Jun 13/73.
Philadelphus lewisii var *gordonianus:* Vancouver, Apr 20/73.
Primula juliae 'Wanda': Victoria, May 18/73.
Primula sp: Vancouver (CDA), Mar 9/75 (In Greenhouse).
Tilia americana: Vancouver (UBC), Jun 11/75.
Tropaeolum majus: North Vancouver, Jun 18/74.
Tulipa gesneriana: North Vancouver, May 25/75.

SPIRAEAE MacGillivray, MASONAPHIS
Previously listed as SPIRAEAE (MacGillivray) due to a typographical error.
Corylus cornuta: Vancouver (UBC), Jun 10/74, Jun 12/74.
Spiraea douglasii: Vancouver (UBC), Jul 15/75.

*SPIRAECOLA (Patch), MASONAPHIS
Spiraea thunbergii: Vancouver (UBC), Jun 18/75.

*SPIROTHECAE Passerini, PEMPHIGUS
Populus nigra var *italica:* Vancouver (UBC), Apr 24/74, Apr 25/74, Apr 26/74, Apr 30/74, May 24/74, Jun 13/74, Jul 5/74, Aug 13/74, Sep 6/74, Sep 27/74, Oct 15/73, Oct 15/74, Oct 16/74, Nov 1/74, Nov 4/74.

STANLEYI Wilson, MACROSIPHUM
Previously listed as STANLEYI (Wilson) due to a typographical error.
Sambucus racemosa var *arborescens:* Vancouver (UBC), Apr 19/75, Apr 30/75, Jun 25/74, Aug 27/74.

STAPHYLEAE (Koch), RHOPALOSIPHONINUS
Vinca minor: Vancouver (UBC), Jun 19/75.

TANACETARIA (Kaltenbach), MACROSIPHONIELLA
Tanacetum vulgare: Texas Lake, Jul 24/67.

TESTUDINACEA (Fernie), PERIPHYLLUS
Acer ginala: Vancouver (UBC), Jun 5/75.
Acer glabrum var *douglasii:* Vancouver (UBC), Jun 5/75.

TILIAE (Linnaeus), EUCALLIPTERUS
Tilia americana: Vancouver (UBC), Apr 29/75, May 16/75, Jun 11/75, Oct 3/75.
Tilia petiolaris: Vancouver (UBC), Jun 5/75, Oct 6/75.

ULMISACCULI (Patch), COLOPHA
Agropyron repens: Laidlaw, Apr 17/74.

*VIBURNICOLA (Gillette), NEOCERURAPHIS
Viburnum opulus: Vancouver, Apr 22/73.

*WAHNAGA Hottes, MASONAPHIS
In flight: Vancouver (UBC), Sep 23/75.

WALSHII (Monell), MYZOCALLIS
Quercus rubra: Vancouver, Aug 30/74; Vancouver (UBC), Aug 29/74.

XYLOSTEI (DeGeer), STAGONA
Previously listed as PROCIPHILUS XYLOSTEI (DeGeer).

*Aphid species not in the previous lists.

References

Forbes, A. R., B. D. Frazer, and H. R. MacCarthy. 1973. The aphids (Homoptera:Aphididae) of British Columbia. 1. A basic taxonomic list. J. ent. Soc. Brit. Columbia 70: 43-57.

Forbes, A. R., B. D. Frazer, and Cho-Kai Chan. 1974. The aphids (Homoptera:Aphididae) of British Columbia. 3. Additions and corrections. J. ent. Soc. Brit. Columbia 71: 43-49.

Hille Ris Lambers, D. 1974. On American aphids, with descriptions of a new genus and some new species (Homoptera, Aphididae). Tijdschrift voor Entomologie 117: 103-155.

Raworth, D. A., and B. D. Frazer. 1976. Compilation of taxonomic catalogues by computer. J. ent. Soc. Brit. Columbia 73:

Richards, W. R. 1961a. North American **Bornerina** Bramstedt and **Betulaphis** Glendenning (Homoptera: Aphididae). Canad. Ent. 93(6):486-494.

________________. 1961b. New genera and species of rose-infesting aphids (Homoptera: Aphididae). Canad. Ent. 93(8): 622-625.

________________. 1969. A review of the holarctic genus **Roepkea** with descriptions of four new nearctic species (Homoptera: Aphididae). Canad. Ent. 101 (11): 1121-1162.

COMPILATION OF TAXONOMIC CATALOGUES BY COMPUTER

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ABSTRACT

The advantages of using a computer are examined for storing, updating, and cross indexing taxonomic collection data in working and published lists.

Records of collections of animals and plants for taxonomic purposes or for compilations of more general lists of fauna and flora are typically and unavoidably voluminous. Difficulty occurs in manually updating, cross indexing and listing data about each collection easily and quickly. However, the data are usually regular, in that information for every collection may be split into several logical and uniform divisions. For example, collection data consistently include taxonomic identification, location of the sample, date, collector, and sometimes a description of the sample and habitat. This regularity suits the data admirably to computer storage and manipulation. The advantage of using a computer is mainly in the speed with which it can extract, arrange and print information. The time saved is appreciable as the data base becomes larger. This paper discusses the use of the computer for maintaining and updating the various lists associated with a collection of aphids from British Columbia.

The aphidologists of our research group have accumulated a data base of more than 1500 collections during the past 20 years. Information is recorded on cards (Fig. 1) at the time a collection is made and these cards are indexed by plant host species. When an aphid is identified these data are also indexed alphabetically by aphid species. About 150 collections are added each year. The task of identifying aphids is made easier by using lists of previously collected aphids and host plants ordered in various ways (1, 2, 3), so that much time has been spent maintaining cross indices by hand.

Computer programming is a time consuming and often costly procedure. Most computing centers, however, maintain a library of those 'canned' programs most often needed by computer users. One such program called 'The UBC Report Generator' (RG), (4) was suited to our needs. The following is a brief description of how RG was used.

RG requires that all collections have the same divisions or fields of data, and that these fields be in a constant order. We ordered our data on three data cards per collection: by aphid genus, species and authority on the first; by host plant family, common name, genus, species and class code on the second; and by location of sample, month number, month, day, year, collector's name and lot number on the third. These fields are separated by commas. Since RG is extremely flexible this is only one of a number of ways in which the data can be organized. The data were then punched on computer cards (Fig. 2) and the card images were stored on magnetic tape for economical computer operations.

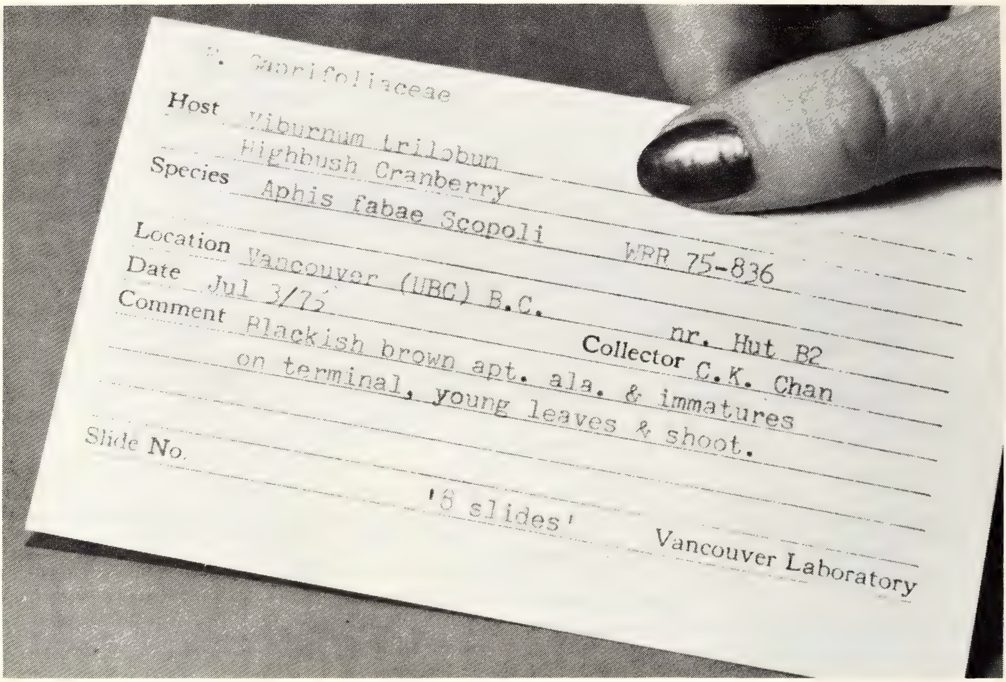

Fig. 1. A completed collection card.

In order to obtain lists, we 'ran' RG with the data, a description of how the data were set up and a series of commands describing what items to extract and how to order and print them (Fig. 3). Many other possibilities exist.

In many instances, field contents may be duplicated from collection to collection and when ordered, appear redundant (Fig. 3a). Although RG does not have the facility to reduce redundancy, it does allow the use of computer language subroutines which can be written to handle the problem. Subroutines were written in FORTRAN IV, to eliminate redundancy (Fig 4) and to provide appropriate punctuation.

The printing capability of the computer is far greater than that indicated by figures 3 and 4 because it has all the necessary typewriter characters and is much faster. Since publishable manuscripts were desirable in addition to working lists, a computer program was written to convert the normal upper case computer card characters to appropriate upper and lower case characters (Fig. 5).

Although RG is a complex program capable of many tasks it is remarkably easy to use, even for those not familiar with computers. Costs are minimal, but of course vary with the quantity and complexity of the lists. Preparation of a list of 1500 collections organized as illustrated (Fig. 3-5) cost between $5.00 and $15.00. The time required is as little as three minutes for the finished product. By far the most difficult and time consuming task is keypunching the original data, but this is done only once.

In conclusion, computer capabilities in taxonomy are limited only by need, time, money and imagination. We hope that greater use will be made of computers for facilitating the manipulation of animal and plant collection data. Their use for this purpose promotes better and more efficient use of the data and frees research and support staff for more interesting duties.

ACKNOWLEDGEMENTS

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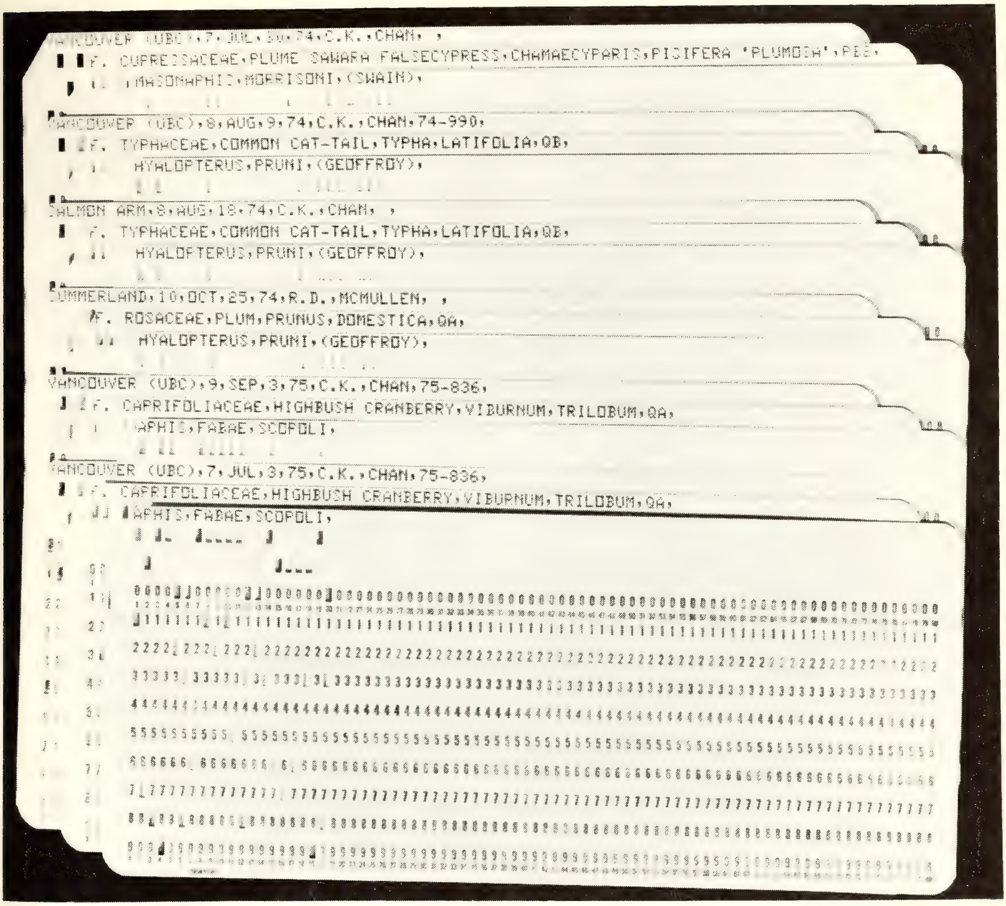

Fig. 2. The collection data on computer cards.

```
CL. PINOPSIDA (CONIFERS)
   F. CUPRESSACEAE CHAMAECYPARIS PISIFERA 'PLUMOSA'
      MASONAPHIS MORRISONI
CL. MAGNOLIOPSIDA (FLOWERING PLANTS - DICOTYLEDONS)
   F. CAPRIFOLIACEAE VIBURNUM TRILOBUM
      APHIS FABAE
CL. MAGNOLIOPSIDA (FLOWERING PLANTS - DICOTYLEDONS)
   F. CAPRIFOLIACEAE VIBURNUM TRILOBUM
      APHIS FABAE
CL. MAGNOLIOPSIDA (FLOWERING PLANTS - DICOTYLEDONS)
   F. ROSACEAE PRUNUS DOMESTICA
      HYALOPTERUS PRUNI
CL. LILIOPSIDA (FLOWERING PLANTS - MONOCOTYLEDONS)
   F. TYPHACEAE TYPHA LATIFOLIA
      HYALOPTERUS PRUNI
CL. LILIOPSIDA (FLOWERING PLANTS - MONOCOTYLEDONS)
   F. TYPHACEAE TYPHA LATIFOLIA
      HYALOPTERUS PRUNI
```

Fig. 3a. All collections of figure 2 extracted and ordered by plant class, family, genus, and species; aphid genus, and species.

```
FABAE SCOPOLI APHIS
   VIBURNUM TRILOBUM VANCOUVER (UBC) JUL3/75
FABAE SCOPOLI APHIS
   VIBURNUM TRILOBUM VANCOUVER (UBC) SEP3/75
MORRISONI (SWAIN) MASONAPHIS
   CHAMAECYPARIS PISIFERA 'PLUMOSA' VANCOUVER (UBC) JUL30/74
PRUNI (GEOFFROY) HYALOPTERUS
   PRUNUS DOMESTICA SUMMERLAND OCT25/74
PRUNI (GEOFFROY) HYALOPTERUS
   TYPHA LATIFOLIA SALMON ARM AUG18/74
PRUNI (GEOFFROY) HYALOPTERUS
   TYPHA LATIFOLIA VANCOUVER (UBC) AUG9/74
```

Fig. 3b. All collections of figure 2 extracted and ordered by aphid species, authority, and genus; plant genus, and species; location, month number, day, and year.

```
APHIS FABAE SCOPOLI
   VIBURNUM TRILOBUM JUL3/75
HYALOPTERUS PRUNI (GEOFFROY)
   TYPHA LATIFOLIA AUG9/74
```

Fig. 3c. All collections of figure 2 extracted where plant class code was 'QA' or 'QB', location contained 'Vancouver', and month number was less than 9.

```
CL. PINOPSIDA (CONIFERS)
   F. CUPRESSACEAE
    CHAMAECYPARIS PISIFERA 'PLUMOSA'
      MASONAPHIS MORRISONI
CL. MAGNOLIOPSIDA (FLOWERING PLANTS - DICOTYLEDONS)
   F. CAPRIFOLIACEAE
    VIBURNUM TRILOBUM
      APHIS FABAE
   F. ROSACEAE
    PRUNUS DOMESTICA
      HYALOPTERUS PRUNI
CL. LILIOPSIDA (FLOWERING PLANTS - MONOCOTYLEDONS)
   F. TYPHACEAE
    TYPHA LATIFOLIA
      HYALOPTERUS PRUNI
```

Fig. 4. Redundancy of figure 3a eliminated.

```
FABAE Scopoli, APHIS
  Viburnum trilobum: Vancouver (UBC), Jul3/75, Sep3/75.

MORRISONI (Swain), MASONAPHIS
  Chamaecyparis pisifera 'Plumosa': Vancouver (UBC), Jul30/74.

PRUNI (Geoffroy), HYALOPTERUS
  Prunus domestica: Summerland, Oct25/74.
  Typha latifolia: Salmon Arm, Aug18/74; Vancouver (UBC), Aug9/74.
```

Fig. 5. Figure 3b in publishable form.

References

Forbes, A. R., B. D. Frazer and H. R. MacCarthy. 1973. The Aphids (Homoptera: Aphididae) of British Columbia. 1. A Basic Taxonomic List. J. Ent. Soc. Brit. Col. 70:43-57.

Forbes, A. R. and B. D. Frazer. 1973. The Aphids (Homoptera: Aphididae) of British Columbia. 2. A Host Plant Catalogue. J. Ent. Soc. Brit. Col. 70:58-68.

Forbes, A. R., B. D. Frazer and Cho-Kai Chan. 1974. The Aphids (Homoptera: Aphididae) of British Columbia. 3. Additions and Corrections. J. Ent. Soc. Brit. Col. 71:43-49.

Miller, A. 1975. The UBC Report Generator. Computing Center, the University of British Columbia, Vancouver, B.C., Canada V6T 1W5.

BOOK REVIEW

Mamaev, B. M. 1974. *Evolution of gall forming insects—gall midges* (English Edition). Translated by A. Crozy, edited by K. M. Harris. Published by The British Library, Lending Division, printed by W. S. Maney Ltd., Leeds, England, 317 pp. 79 figs. Size 6" x 8½" (15.5c x 22c). Paper cover. Price *L* 8.50, + $15.00. (Translation of Russian Edition, published by "Nauka", Leningrad, 1968).

This book is a monograph of the family Cecidomyiidae that focuses on the origins, the lines and the patterns of evolution. It defines the family, the subfamilies, the tribes and subtribes in terms of the morphology, anatomy and ecology of all stages, but it contains no taxonomic keys. The author's primary purpose is to outline the evolutionary development of gall midges, and from this, to construct a logical classification. Thus, the classification adopted in the first chapter is, in effect, the practical outcome of the contents of the remaining seven chapters. The book is the culmination of 15 years work, beginning in 1951, on the native gall midge fauna of the European U.S.S.R., the Caucasus, Central Asia and the Far East. The collation of collections from different habitats (soil, litter, wood and living plant tissues) from these geographically distant and ecologically distinct areas (forests, steppes, deserts and mountains) provide the factual bases for the theoretical constructions developed.

Dr. Mamaev is well qualified to undertake such a project. He obtained his Ph.D under Prof. E. S. Smirnov, Head, Department of Entomology, Moscow State University, about 1951, and then went to work at the Institute of Evolutionary Morphology and Ecology of Animals, (Laboratory of Soil Zoology) Soviet Academy of Sciences in Moscow. Since then he has been a prolific researcher (author or coauthor of 38 papers cited in the book), especially on Cecidomyiidae. All his work has been based on a multidisciplinary approach and most of his findings reflect a thoroughness and a soundness rarely encountered. His book is based largely on his own findings, coupled with first-hand information from colleagues with similar interests. Thus his book is built on a solid foundation of personal investigations and knowledge, and is much more than a synthesis of previously published data.

Part one, consisting of four chapters, deals primarily with the morphological aspects of the evolution of gall midges. Chapter one consists of diagnoses of the family, subfamilies, tribes and the subtribes; it also provides a modern classification of the family breaking it into two subfamilies: the Lestremiinae with three tribes, Lestremiini, Moehniini (since eliminated because the only known species belongs to the Sciaridae), and Micromyiini, and the Cedicomyiinae with six tribes, Heteropezini, Porricondylini, Oligotrophini, Lasiopterini, Ceci-

domyiini and Asphondyliini. Chapter two describes the evolution of the larvae from the standpoints of morpho-ecological types, adaptive changes in the integument, the head structures and the digestive systems. Chapter three deals with the evolution of the adults in a similar manner but with special emphasis on development of winglessness, changes in sense organs, and the form of the male and female terminalia. Chapter four is an analysis of the occurrence patterns of morphological characters in larvae and adults, ending in a dendrogram showing the "phylogenetic links of the major taxonomic groups of gall midges." Of special interest is a discussion on the exchange of secondary sexual characters between males and females, e.g., feminization of antennae in males, and the significance of such phenomena in classification. Unfortunately the dendrogram (Fig. 45) summarizing the ideas of this chapter is poorly organized. It shows the subfamily Cecidomyiidae as a monophyletic group arising from a single subtribe (Catochina) of the Lestremiinae. This, in effect, makes the Cecidomyiinae a sister-group of the subtribe Catochina and makes the subfamily Lestremiinae a paraphyletic group. In the text, however, and in a subsequent phylogenetic chart (Fig. 79) the Cecidomyiinae are correctly treated as a sister-group of the Lestremiinae, i.e., arising from the common ancestor of all Cecidomyiidae.

The second half of the book also contains four chapters and deals mainly with the ecological aspects of the evolution of the gall midges. Chapter five considers the ecological prerequisites for proliferation of gall midges—adaptations for expansion into different hosts and geographic areas, and adaptations for intensifying the multiplication and survival of species. Chapter six deals with the ecological pathways leading to mycetophagy, phytophagy and gall formation; it also includes discussions on gall midges as plant parasites and on the importance of flowers in their evolution. Chapter seven treats special aspects of gall fly speciation and gall formation in plants; one of the main points made is that host data and the forms of the galls are not always reliable criteria for species identification. Chapter eight reviews the paleontological data relating to gall midges, and discusses the main stages of evolution of the family in relation to geological ages, ecological backgrounds and the evolution of plants. The author concludes that the Cecidomyiidae are a sister-group of the Mycetophilidae and he provides a phylogenetic chart showing the evolution of all the tribes within the family. The final pages include an appendix outlining techniques for collecting and studying gall midges, lists of references in Roman and Cyrillic alphabets and an index of the Latin names of insects referred to in the text.

The book fulfills a real need for this large and difficult group, possibly the largest family of Diptera. The author has managed successfully to analyse and synthesize an immense amount of information from the whole spectrum of biosystematics and to construct a classification that appears to be both practical and in harmony with the evolutionary patterns of the group. He has introduced a wealth of new facts and ideas and has provided a very real addition to our knowledge on almost all aspects of the biology and systematics of these flies. No other book covers the subject so thoroughly or so well. As the author himself states, however, refinements and improvements will appear as further progress is made on this and related families. For example, the genus *Moehnia* (known from females only of one species) is now known to be an aberrant member of the Sciaridae, thereby eliminating one of the tribes of the Lestrimiinae. Such developments are to be expected and do not reduce the overall value of the book.

This edition is a translation, and the translator and the editor have wisely adhered to a policy of exactly portraying the thoughts of the author rather than producing smooth, beautiful English. This results in a style that is sometimes heavy and awkward, but in general Messrs. Crozy and Harris are to be complimented for an easily readable rendition. The author's method of providing separate conclusions at the end of each chapter has resulted in a certain amount of repetition, but this is not a bad fault. The book itself was printed by photographic means from typewritten pages, and it has the general appearance of a xeroxed thesis. The right margin of each page is very uneven and in a few instances (pp. 22, 134) the reproduction is poor; the half tone photographs (about half the figures) also suffered as a result of this type of reproduction. The paper is of good quality, but the bindng is extremely poor; many pages of my copy have become detached from the spine of the book.

There can be no doublt that his work represents a very significant step forward in our knowledge of gall midges, and that it will be a basic reference for many years. Anyone who has any interest in the family should have a copy.

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PEST MANAGEMENT: FOUR YEARS EXPERIENCE IN A COMMERCIAL APPLE ORCHARD

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ABSTRACT

Pest management in a 12 ha apple orchard from 1973 to 1976 resulted in a 50 percent reduction in the number of sprays that are normally applied to control insects and mites. Codling moth, *Laspeyresia pomonella* (L.), populations were monitored by sex pheromone traps and populations of other insects and mites were assessed by specific sampling techniques. Leafrollers were the most difficult pests to control and fruit injury was 1.5 to 2.0 percent in 3 of the 4 years. Mites were held below treatment levels by the predator, *Typhlodromus occidentalis* Nesbitt, except for the apple rust mite, *Aculus schlechtendali* (Nalepa) which required chemical control.

INTRODUCTION

Six commercial apple orchards were pest managed from 1973 to 1976 in order to validate sampling techniques and economic injury levels for major apple pests. This paper examines the data from one of these orchards over a 4-year period. Pest intensity varies from orchard to orchard, and date from one site is not completely representative of all areas. However, it does illustrate the efficiency of procedures and the value of pest management as a method of pest control.

METHODS

The pest managed orchard was located in East Kelowna, B.C. in the heart of an apple and cherry growing area. It was 12 ha in size and planted to 4 apple cultivars, McIntosh, Spartan, Red Delicious and Golden Delicious. The McIntosh and Spartan trees were in solid blocks and the Red Delicious were interplanted with Golden Delicious. All trees were standard plantings with variable planting distances. Previous to 1973, the orchard was sprayed routinely following recommendations in the B.C. Tree Fruit Production Guide and received ca. 7 applications each season.

The following pests were monitored during the 4-year study: European fruit scale, *Quadraspidiotus ostreaeformis* (Curtis); San Jose scale, *Quadraspidiotus perniciosus* (Comstock); fruittree leafroller, *Archips argyrospilus* (Walker); European leafroller, *Archips rosanus* (Linnaeus); codling moth, *Laspeyresia pomonella* (Linnaeus); western flower thrips, *Frankliniella occidentalis* (Pergande); the mirid *Campylomma verbasci* (Meyer); white apple leafhopper, *Typhlocyba pomaria* McAtee; eyespotted budmoth, *Spilonota ocellana* (Denis & Schiffermüller); apple aphid, *Aphis pomi* DeGeer; European red mite, *Panonychus ulmi* (Koch); McDaniel spider mite, *Tetranychus mcdanieli* McGregor; and apple rust mite, *Aculus schlenchtendali* (Nalepa).

Sampling methods and economic injury thresholds for the above pests have been described by Madsen et al. (1975). A few modifications in sampling methods and a few changes in economic injury thresholds were made after the above paper was prepared. The treatment level for fruittree leafroller was reduced from 10 larvae per 100 leaf clusters to 5 because injury was 1 to 2 percent when the treatment level was 10.

We devised a new method of assessing thrips populations. A sample of blossom clusters was placed in a Berlese funnel and left there for 6 hours. As the blossoms wilted, the thrips moved down and were captured in a jar of alcohol at the base of the funnel. This method was quicker and more accurate than the previously used extractor.

The treatment level for *Campylomma verbasci* was reduced from 5 nymphs per limb tap sample to 2. Although *C. verbasci* was not a problem in the orchard described in this paper, evidence from other orchards indicated that a level of 5 per limb tap resulted in ca. 3 to 4 percent fruit injury.

Although 2 species of leafrollers were present in the orchard, their seasonal history and behavior is similar and they cause the same type of damage to apples (Madsen et al. 1976). Therefore, all fruit with leafroller injury was placed in a single category.

The effectiveness of the program was assessed by harvest samples for insects that attack fruit directly. A total of 250 apples per bin were examined while the fruit was being picked and fruit injury by the various pests was recorded. We sampled a minimum of ⅓ of the total bins picked for each apple cultivar. Pests that attack leaves and do not directly affect fruit were assessed by rating leaf injury if populations exceeded the treatment level.

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RESULTS AND DISCUSSION

Codling moth is the key pest in an apple management program because chemical control directed against this insect affects other pests as well as natural enemies. The data on codling moth monitoring in this orchard during 1973 and 1974 have been discussed by Vakenti and Madsen (1976). In 1973, sex pheromone traps indicated low codling moth populations within the orchard, but high numbers in neighboring orchards. No sprays were applied and the percent injured fruit at harvest was only 0.1 (Table 1). We have calculated that a codling moth infestation of 0.5 can be tolerated by orchardists and does not justify the cost of a spray application (Vakenti and Madsen 1976). In 1974, trap captures indicated a need for treatment on 3 occasions, but the moth numbers were only slightly above the treatment level of 2 per trap. We suggested chemical control but the orchardist chose not to apply a spray. The codling moth injury at harvest was 0.7 percent which indicated at least one spray would have been justified.

Fig. 1 illustrates the codling moth captures for 1975 and 1976. The traps captured an average of over 4 per trap in early June of 1975 and a codling moth spray was applied a week later. No further sprays were applied although the moth capture was slightly above treatment level the first week of July. In 1976, the treatment level was exceeded during the week of July 12, but over 70 percent of the moths were captured in a single block of Red and Golden Delicious trees. We suggested that treatment be limited to this area which was ca. ⅓ of the total orchard. A single application was applied to this block and was the only codling moth spray the orchard received. Fruit injury by codling moth was well below the acceptable level of 0.5 percent in both years. During the 4-year period, only 1⅓ sprays were applied for codling moth control in contrast to a calendar based program which would have required a minimum of 8 treatments.

Leafrollers required treatment in all 4 years, but control from 1973 to 1975 was not as effective as expected. Diazinon was used until 1975 when there was evidence of tolerance by leafrollers to this pesticide from orchards in the same general area (Madsen and Carty 1977). In 1976, azinphosmethyl was used instead of diazinon, and fruit injury was reduced by ca. 90 percent from the previous year.

Injury by eyespotted budmoth was negligible and noted only in 1975 and 1976. Thrips injury, represented by pansy spot on McIntosh and Spartan cultivars, was variable and our earlier sampling method did not detect populations that caused 2 percent injury in 1973. The population when sampled by the Berlese funnel method indicated a treatment level in 1975, but the grower chose not to spray. It is doubtful if a spray would have been justified since fruit injury was less than 1 percent.

Campylomma verbasci was not present in sufficient numbers to be of concern in this orchard. White apple leafhopper populations

Table 1. Summary of pest management — Fitzgerald Orchard, Kelowna, 1973-1976.

Pest	Number of sprays applied, percent fruit injury and degree of foliage injury							
	1973		1974		1975		1976	
	S	I	S	I	S	I	S	I
Codling moth[1]	0	0.1	0	0.7	1	0.2	⅓	0.1
Fruittree leafroller and European leafroller[1]	1	2.0	1	1.5	1	1.6	1	0.2
Eyespotted budmoth[1]	0	0.0	0	0.0	0	0.1	0	0.1
Thrips[1]	0	2.1	0	0.0	0	0.8	0	0.0
Campylomma verbasci[1]	0	0.0	0	0.1	0	0.0	0	0.1
San Jose scale[1]	0	0.0	0	0.0	0	0.0	0	0.0
European fruit scale[1]	0	0.0	0	0.0	0	0.0	0	0.0
White apple leafhopper[2]	0	nil	0	nil	0	nil	1	nil
Apple aphid[2]	0	nil	o	nil	0	nil	0	nil
European red mite[2]	1	nil	1	nil	½	nil	1	nil
McDaniel spider mite[2]	0	nil	0	nil	0	nil	0	nil
Apple rust mite[2]	1	+[3]	1	nil	¼	nil	0	nil

[1]damage assessed by fruit injury.
[2]damage assessed by leaf injury.
[3]+= slight damage, no effect on Apple quality.
Abbreviations: S=sprays, I=injury.

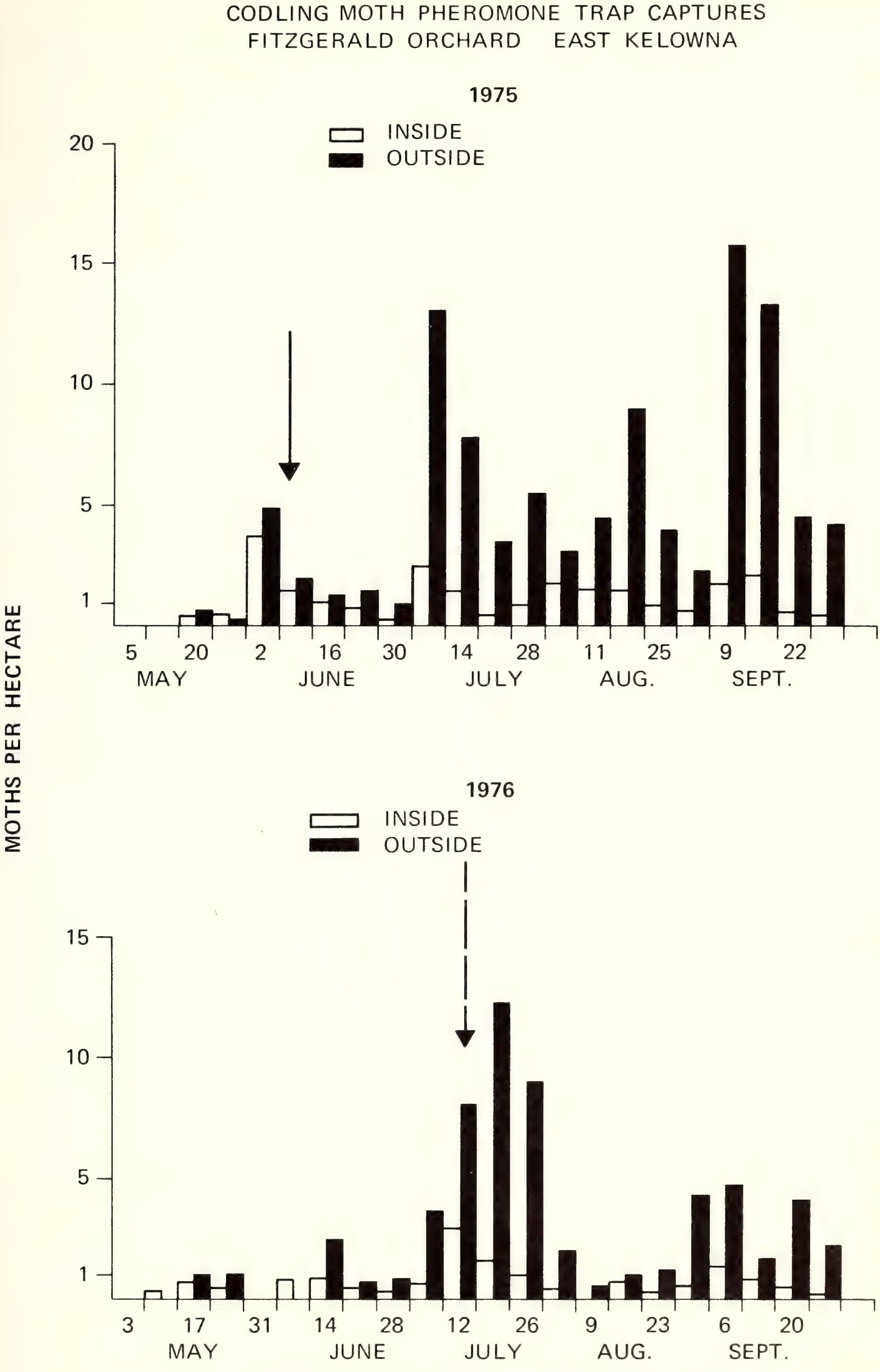

Fig. 1. Codling moth pheromone trap captures 1975-1976.

Arrows indicate date of spraying. Unbroken arrow=entire orchard sprayed, broken arrow=⅓ of orchard sprayed.

were below treatment levels from 1973 to 1975, but a spray was required in 1976. Apple aphid was present on young trees in all 4 years, but colonies were restricted to terminal growth and populations did not reach treatment level.

Mites were not a problem in the orchard during the 4-year experiment except for apple rust mite. The principal mite predator in British Columbia orchards, *Typhlodromus occidentalis* Nesbitt, increased during the first year of pest management and there was an excellent ratio of predators to phytophagous mites during the subsequent 3 years. The sprays in Table 1 for European red mite control were delayed dormant oil treatments directed against overwintered eggs. Downing and Arrand (1976) stated that a delayed dormant oil spray is often necessary to ensure that integrated mite control programs will be successful. Apple rust mite increased to treatment level in 1973 and 1974 and light foliage injury occurred in 1973 although a spray was applied. In 1975, one block of Red Delicious trees required a spray for apple rust mite control and no leaf injury was detected.

No San Jose scale or European fruit scale was encountered in any of the harvest samples. European fruit scale is prevalent in other orchards in this area and packinghouses have advised growers to spray routinely. Our management techniques did not indicate a need to spray for this pest, but the dormant oil spray used for European red mite eggs probably had an effect on any scales that were present.

Over the 4-year period, 14 applications were made for pest control which is a 50 percent reduction over a calendar based spray program. On the whole, results in other pest managed orchards were similar and the number of sprays necessary to obtain control was reduced by 35 to 50 percent. The cost of an advisory program has been calculated as $50 per ha (Haley 1976). To apply a single spray of azinphosmethyl for codling moth or leafroller control costs ca. $25 per ha for the material alone. It is evident that the cost of an advisory program would be realized if the yearly spray program were reduced by 2 applications. Another advantage of pest management which has seldom been mentioned is improved control when it is necessary to spray. Timing of sprays is more accurately based upon samples rather than on calendar dates or phenological data used in production guides.

References

Downing, R. S. and J. C. Arrand. 1976. Integrated control of orchard mites on apple in British Columbia. Can. Ent. 108. 77-81.

Haley, Sue. 1976. Apple pest management in the North Okanagan Valley, British Columbia: A feasibility study. M.A. Thesis, Simon Fraser University, Burnaby, B.C. 1-48.

Madsen, H. F., F. E. Peters and J. M. Vakenti. 1975. Pest management: Experience in six British Columbia apple orchards. Can. Ent. 107: 873-877.

Madsen, H. F., and F. E. Peters. 1976. Pest management: Monitoring populations of *Archips argyrospilus* and *Archips rosanus* (Lepidoptera: Tortricidae) with sex pheromone traps. Ibid 108: 1281-1284.

Madsen, H. F. and B. E. Carty. 1977. Fruittree leafroller (Lepidoptera: Tortricidae): Control of a population tolerant to diazinon. J. Econ. Ent. (in press).

Vakenti, J. M. and H. F. Madsen. 1976. Codling moth (Lepidoptera: Olethreutidae): Monitoring populations in apple orchards with sex pheromone traps. Can. Ent. 108: 433-438.

PHYTOSEIULUS PERSIMILIS (ACARINA: PHYTOSEIIDAE) FOR CONTROL OF TWO-SPOTTED MITES IN A COMMERCIAL GREENHOUSE[1]

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ABSTRACT

Natural infestations of the twospotted spider mite were controlled on greenhouse cucumber by early releases of the predatory mite, *Phytoseiulus persimilis* Athias-Henriot. Later sporadic mite outbreaks severely damaged some plants and required frequent surveys and repeated predator releases in the greenhouse. However, no mite sprays were required and crop yield was satisfactory.

INTRODUCTION

Chemical control of the twospotted spider mite, *Tetranychus urticae* Koch, on greenhouse cucumbers is becoming increasingly difficult in British Columbia. A number of reports have been published on the use of the predaceous mite, *Phytoseiulus persimilis* Athias-Henriot, for control of spider mites on greenhouse cucumbers (Chant 1961; Gould 1970, 1971; Scopes and Parr 1971; Anonymous 1972). This paper reports the results of a preliminary trial in British Columbia using *P. persimilis* for control of the twospotted spider mite on cucumber in a commercial greenhouse.

METHODS

A commercial greenhouse containing 1300 parthenocarpic cucumber plants on 12,500 sq. ft. (0.12 hectare) was examined on March 24 for infestations of twospotted spider mites. Fifty-nine infested plants were tagged and 400 predator mites released among them. Predators were distributed by tapping 2 to 5 specimens from a glass vial onto a cucumber leaf on each infested plant. Five leaves, on each tagged, infested plant were then examined periodically for host and predator mites.

Tagged plants received no further predators, but 2200 were distributed throughout the remainder of the planting on April 1, and 2400 on June 11. An additional 1600 predators were used to combat localized outbreaks of mites during April and May.

RESULTS AND DISCUSSION

Table 1 shows that twospotted spider mites on tagged, infested plants were eliminated by mid-May, about 55 days after predator mites were released. However, sporadic localized outbreaks of mites occurred in the planting during May and part of June. Some plants were severely damaged, but losses were not serious in relation to the total planting. Predators were abundant throughout the planting by June 21, and no further mite outbreaks occurred. Both host and predator mites had disappeared from all plants by mid-July. There was no recurrence of twospotted spider mites before the plants were removed in early August.

The introduction of red spider mites in a planting before releasing predators has been recommended in England to establish a predictable predator-prey interaction (Anonymous 1972). In our trials, predators were released in naturally occurring mite infestations. Plants with well-established infestations almost invariably suffered severe damage before the predators achieved control.

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TABLE 1. Percentage of leaves with **T. urticae**, and **T. urticae** plus **P. persimilis**, following the release of predatory mites. A total of 295 leaves were examined on each sampling date.

Days after Predator Mite Release	% Leaves with T. urticae	% Leaves with T. urticae and P. persimilis
22	38	68
43	19	88
55	1	100
71	nil	nil

In addition, sporadic outbreaks of mites required frequent monitoring of the planting and repeated releases of predators. Nevertheless, we feel that the trial was successful. Economic control of mites was achieved when predators were released early in the development of mite infestations. No mite sprays were required in the test planting, and cucumber yields were satisfactory throughout a normal cropping period. This contrasted with conditions in the same greenhouse during the previous season, when plant damage from mites and frequent acaricide applications shortened the cropping period by 3 to 4 weeks.

References

Anonymous. 1972. The biological control of cucumber pests. Growers Bull. No. 1, Glasshouse Crops Research Institute, Littlehampton, Sussex.

Chant, D. A. 1961. An experiment on the biological control of ***Tetranychus telarius L.*** in a greenhouse using **Phytoseiulus persimilis** A.H. Canad. Ent. 93: 437-443.

Gould, H. J. 1970. Preliminary studies of an integrated control program for cucumber pests and an evaluation of methods of introducing **Phytoseiulus persimilis** Athias-Henriot for the control of **Tetranychus urticae** Koch. Ann. appl. Biol. 66: 503-513.

Gould, H. J. 1971. Large scale trial of an integrated control programme for cucumber pests on commercial nurseries. P1. Path. 20: 149-156.

Scopes, N. E. A. and W. J. Parr. 1971. Big decision on predator control must be made. Grower 75 (13): 794-798.

A METHOD FOR REARING THE PREDACEOUS MITE, *PHYTOSEIULUS PERSIMILIS* (ACARINA: PHYTOSEIIDAE)

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ABSTRACT

The predaceous mite, *Phytoseiulus persimilis* Athias-Henriot, was reared successfully in a darkened growth chamber on blotting paper on a freezer carton lid floated on water in a plastic saucer. Predators were fed with twospotted spider mites collected from infested bean leaves with a mite brushing machine.

INTRODUCTION

During studies initiated on the biological control of the twospotted spider mite, *Tetranychus urticae* Koch on greenhouse cucumbers, we needed a simple method for rearing the predaceous mite, *Phytoseiulus persimilis* Athias-Henriot. Techniques for mass-rearing both host and predaceous mites have been published (McMurtry and Scriven 1965, Scopes 1968, Scriven and McMurtry 1971, Anonymous 1975). This report describes adaptations and innovations developed for our own conditions and facilities.

METHODS AND DISCUSSION

We reared twospotted spider mites on bush beans *(Phaseolus vulgaris* L. cv. Stringless Greenpod) grown in 3:2:1 soil-peat-sand mix, planting 4 seeds in each 15 cm diameter plastic pot. When the plants are about 30 cm high, they are transferred to a growth chamber maintained at 25‡1°C with 16 hours of light.

Predaceous mites are reared in darkness at 25‡1°C. Each culture is started by transferring 30 predaceous mites to a 9 cm disc of blotting paper. This paper is placed on an inverted 12 cm diameter lid from a freezer carton (Plasti-Pak Containers, Toronto, Canada). Wandering by the mites is minimized by floating the lid on water in a plastic saucer 25 cm in diameter and 4.5 cm deep. The lid is centred in the saucer by attaching one small magnet to the bottom of the lid and a second magnet in the bottom of the saucer. Another 25 cm plastic saucer is inverted over the culture as a cover to maintain a high relative humidity within the container.

Each predaceous mite culture is fed with twospotted spider mites removed from infested bean leaves with a mite brushing machine (Henderson and McBurnie, 1943). We found

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[1]J. W. Gates, personal communication

that many mites were injured when leaves were passed between both brushes of the machine, so we removed one brush. The leaf can be then pressed and moved gently against the remaining brush with the hand until all the mites are removed. Apparently the same effect can be achieved on some machines by reversing the belt drive so that the brushes rotate outwards[1]. The mites are collected on a 12 cm blotting paper disc and tapped off or brushed from the paper onto the predator culture.

Cultures develop satisfactorily if fed three times a week. Rate of increase varies among cultures, but we have obtained 400 to 1000 predators from single cultures after 3 to 4 weeks. One culture will remain productive for many weeks, but after about 6 weeks debris accumulation interferes with collecting. Collections are made with a small suction aspirator. One person can collect at least 1000 mites an hour from vigorous cultures. Although predators survive only a few hours when they are collected in vials without any host mites, they survive about 7 days in vials containing mite-infested bean leaf sections.

Our relatively small demand for predaceous mites required the services of one person for about 3 hours per week. This includes planting about 20 pots of beans per week, maintaining established plants and feeding 6 to 10 cultures. The whole rearing procedure can be readily expanded or reduced according to demand.

References

Anonymous. 1975. Biological pest control - rearing parasites and predators. Bull. No. 2, Glasshouse Crops Research Institute, Littlehampton, Sussex.

Henderson, C. F. and H. Y. McBurnie. 1943. Sampling techniques for determining populations of citrus red mite and its predators. U.S. Dep. Agric. Circ. 671.

McMurtry, J. A. and G. T. Scriven. 1965. Insectary production of Phytoseiid mites. J. Econ. Ent. 58: 282-284.

Scopes, N. E. A. 1968. Mass rearing of **Phytoseiulus riegeli** Dosse for use in commercial horticulture. Pl. Path. 17: 123-126.

Scriven, G. T. and J. A. McMurtry. 1971. Quantitive production and processing of Tetranychid mites for large-scale testing or predator production. J. Econ. Ent. 64: 1255-1257.

THE FIRST RECORD OF *CULISETA SILVESTRIS MINNESOTAE* BARR IN BRITISH COLUMBIA (DIPTERA: CULICIDAE).

Curtis (1967) speculated that *Culiseta silvestris minnesotae* likely occurred in British Columbia since it has been taken near the southern boundaries of the province. During a routine light-trap survey in the municipality of Port Coquitlam, a suburb of Vancouver, British Columbia, two *C.s. minnesotae* females were collected on July 12 and August 14, 1974. The larvae of this species have not yet been found in British Columbia.

Originally described by Barr (1957) as *Culiseta minnesotae*, Stone (1967) assigned it as a subspecies of *Culiseta silvestris* Shengarev.

This finding brings the total number of mosquito species recorded in British Columbia to 41, and extends the known Canadian range of this species from Ontario to the West Coast.

I wish to thank Dr. D. M. Wood of the Biosystematics Research Institute, Agriculture Canada, Ottawa, for confirming my tentative determination of these specimens.

References

Barr, A. R. 1957. A new species of **Culiseta** (Diptera: Culicidae) from North America. Proc. Ent. Soc. Wash. 59: 163-167.

Curtis, C. L. 1967. Mosquitoes of British Columbia. Occasional Papers, B.C. Provincial Museum, No. 15, 90 pp.

Stone, A. 1967. A synoptic catalogue of the mosquitoes of the world, Supplement III (Diptera: Culicidae). Proc. Ent. Soc. Wash. 69: 197-224.

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DISTRIBUTION OF *COLEOPHORA LARICELLA* (LEPIDOPTERA: COLEOPHORIDAE) AND ITS MAJOR PARASITES IN THE CROWNS OF WESTERN LARCH IN BRITISH COLUMBIA[1]

BY GORDON E. MILLER[2] AND THELMA FINLAYSON[2]

ABSTRACT

The distribution of *Coleophora laricella* (Hbn.) and its parasites *Dicladocerus* spp. *(D nearcticus* Yosh. and *D. pacificus* Yosh. (Yoshimoto 1976)) and *Spilochalcis albifrons* (Walsh) in the crowns of western larch were determined for five classes of trees. In open-grown trees more than 7.6 m high, *C. laricella* densities were greater at 1.5-3.1 m than at 6.1-7.6 m above the ground, on the sunny side of a tree than on the shaded side, and on the outer half than on the inner half of a branch. In open-grown trees 3.0-4.6 m high and in trees forming a closed canopy, only the outer branch halves had significantly greater densities. The only significant variation in parasitism by *Dicladocerus* spp. occurred between branch halves in open-grown, non-roadside trees more than 7.6 m high, with more parasitism on the inner halves than the outer. Parasitism by *S. albifrons* was significantly greater at the lower crown level than at the higher in open-grown, closed-canopy, non-roadside trees that were more than 7.6 m high, and on the outer branch half than on the inner half in the same category of tree.

INTRODUCTION

Little is known about the within-tree distribution of the larch casebearer, *Coleophora laricella* (Hbn.) (Lepidoptera: Coleophoridae), an introduced pest, and its major parasites in British Columbia, in trees growing in different situations. It is thus difficult to develop adequate sampling procedures. *Dicladocerus* spp. *(D. nearcticus* Yosh. and *D. pacificus* Yosh. (Yoshimoto 1976) (Hymenoptera: Eulophidae) and*Spilochalcis albifrons* (Walsh) (Hymenoptera: Chalcididae) were by far the most abundant species in a two-year survey of parasites of *C. laricella* (Miller and Finlayson 1974, 1977).

Webb (1953) examined the distribution of *C. laricella* on American larch, *Larix laricina* (Du Roi) K. Koch, but only on large, open-grown trees. There have been no published reports of within-tree distribution of *C. laricella* in western larch, *Larix occidentalis* Nutt. Distributions of *Dicladocerus* spp. and *S. albifrons* on western larch have been reported by Tunnock *et al.* (1972), but again only on large, open-grown trees.

The objective of this study was to determine the within-tree distributions of *C. laricella, Dicladocerus* spp. and *S. albifrons* in western larch trees growing in various situations, to provide data that could improve sampling techniques.

METHODS

Crowns of 40 western larch trees in five classes were sampled on 13 June 1974 at Shoreacres, British Columbia. The five classes of trees and the number in each class were:

Class	Description	Number of trees
1	Open-grown trees at least 91.4 m (100 yd.) from road and over 12.2 m (40 ft.) high	10
2	Same as Class 1 except 7.6-10.7 m (25-35 ft.) high	10
3	Same as Class 1 except 3.1-4.6 m (10-15 ft.) high	5
4	Same as Class 1 except trees were roadside	5
5	Same as Class 1 except trees formed closed canopy. Trees sampled were at least twice height of trees from the edge of stand	10

[1]Based on a thesis submitted by the senior author in partial fulfillment of an M.Sc. degree

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Samples from Class 1 trees were also taken on 15 May 1974 but were analyzed for distribution of *C. laricella* only.

Samples were taken at two crown levels: 1.5-3.1 m (5-10 ft.) and 6.1-7.6 m (20-25 ft.) above the ground. Two primary branches were taken from both the sunny and shaded sides of each tree from each crown level and cut in half. The branch halves were mass-reared in pairs according to tree, crown level, side of tree, and branch half. Rearing was done in 30.5x61.0x 30.5 cm (1x2x1 ft.) cages constructed from corrugated paper cartons, the tops of which were replaced with 0.2 mm mesh.

Parasites were collected daily and placed directly into 70% ethanol. After parasite emergence was completed, host cases were removed manually and the number of fascicles counted.

For statistical analyses, $\log_{10}$ x transformations were done on *C. laricella* densities (number per 100 fascicles) and arcsine transformations were calculated for percentage parasitism data. In analyses of variance (Dixon 1973) of the intra-tree distributions of each class, trees were allowed to go random, resulting in conservative F values. The data are presented in the untransformed form.

RESULTS

There were no significant differences between the tree classes in mean density of *C. laricella* or mean percentage parasitism by *Dicladocerus* spp. or by *S. albifrons* in the crown levels (Table 1). *C. laricella* densities varied significantly between crown levels, between sides of the tree, and between branch halves in Classes 1, 2 and 4; and between branch halves only in Classes 3 and 5 (Figure 1). The densities were significantly higher on the outer branch halves than on the inner in all classes. Significantly higher densities occurred at the lower crown level than at the higher in Classes 1, 2 and 4 but no significant differences occurred between crown levels in Class 5. Densities were also significantly higher on the sunny sides of trees than on the shaded sides in Classes 1, 2 and 4 but no significant differences between sides of trees occurred in Classes 3 and 5. The distributions did not differ in Class 1 trees between the two collections.

The only significant variation in parasitism by *Dicladocerus* spp. occurred between branch halves, with more parasitism on the inner than on the outer halves, in Classes 1 and 2 (Fig. 2).

No significant variations occurred between crown levels or sides of trees in any of the classes, or between branch halves in Classes 3, 4 and 5.

Parasitism by *S. albifrons* was significantly greater at the lower crown level than at the higher in Classes 1, 2 and 5; and on the outer branch halves than on the inner in Classes 1 and 2 (Fig. 3). No significant differences occurred between branch halves in Classes 3, 4 and 5, or between crown levels in Class 4.

DISCUSSION

Webb (1953) found distributions of *C. laricella* similar to those in the crown levels and branch portion in open-grown tree classes 1 to 4 of this study, i.e., higher casebearer densities at the bottom of the crown than at the top and on the terminal part of the branch than at the base. The abundance of *C. laricella* larvae and pupae on the sunny side of the tree and the outer half of the branch may reflect the oviposition site preferences of the female moths

TABLE 1. Density of **Coleophora laricella** and percentage parasitism by **Dicladocerus** spp., and by **Spilochalcis albifrons** in five classes of trees on 13 June 1974 at Shoreacres, British Columbia. ($\bar{X}$ = mean, SD = standard deviation)

Class	Crown Level (ft.)	C. laricella density (no./100 fascicles)		% Parasitism Dicladocerus spp.		% Parasitism S. albifrons	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
1	5-10	19.1	5.7	6.5	2.6	9.1	4.1
	20-25	9.7	2.6	8.4	2.9	4.2	3.1
2	5-10	19.4	4.5	7.1	2.3	10.3	4.7
	20-25	8.7	1.9	7.7	2.1	5.8	3.8
3	5-10	13.2	2.8	9.7	1.6	7.3	2.6
	20-25	11.0	2.2	9.4	5.0	3.1	3.4
4	5-10	23.1	3.2	5.0	1.6	7.6	3.5
	20-25	10.8	2.3	6.9	3.4	2.8	2.8
5	5-10	17.2	2.8	6.6	4.3	11.2	5.8

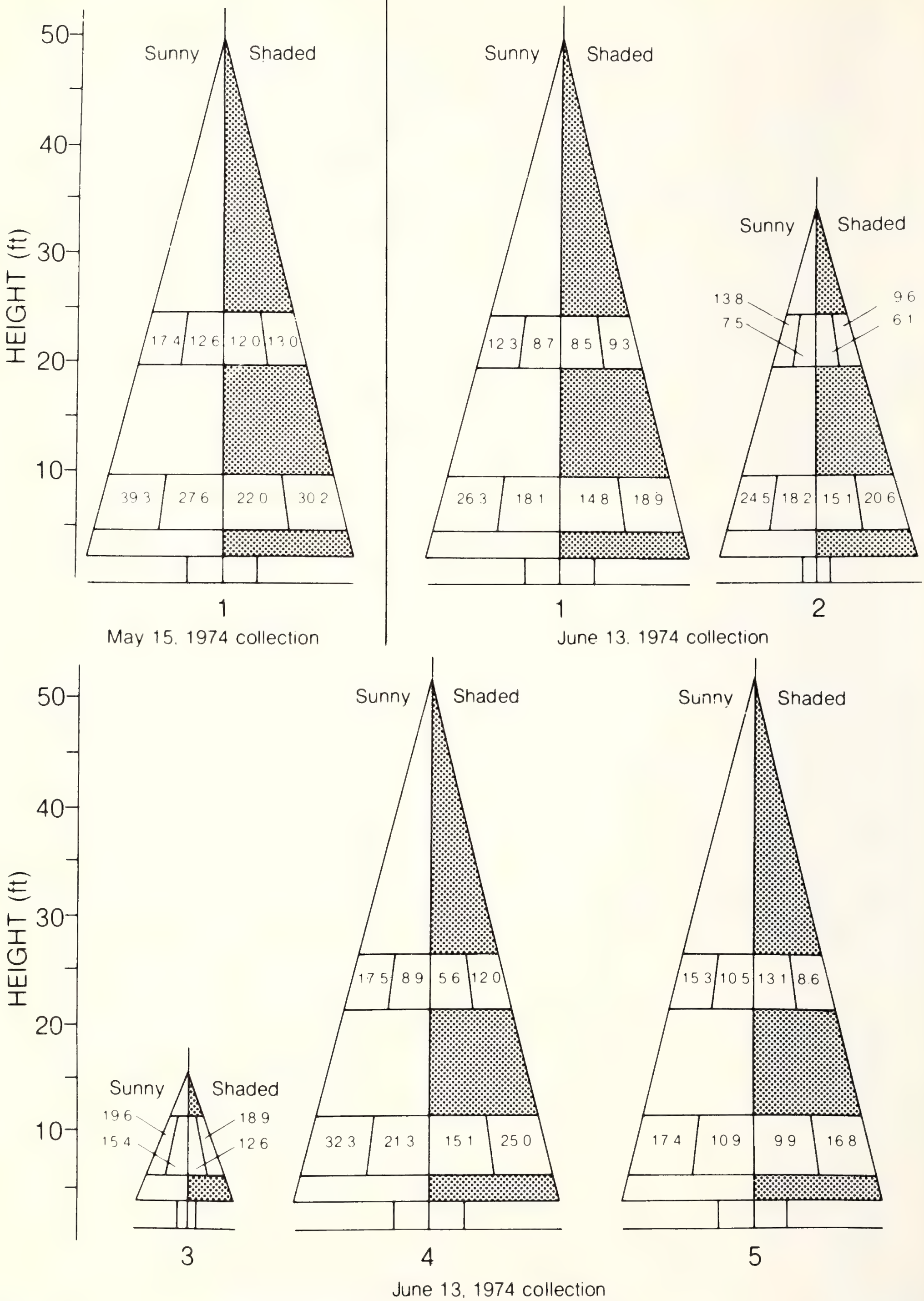

Fig. 1. Schematic representation of within-tree distributions of **Coleophora laricella** in one class of tree on 15 May 1974 and five classes of trees on 13 June 1974 at Shoreacres, British Columbia. (Numbers represent number of casebearers per 100 fascicles, the outer being those of the outer branch half and the inner those of the inner branch half)

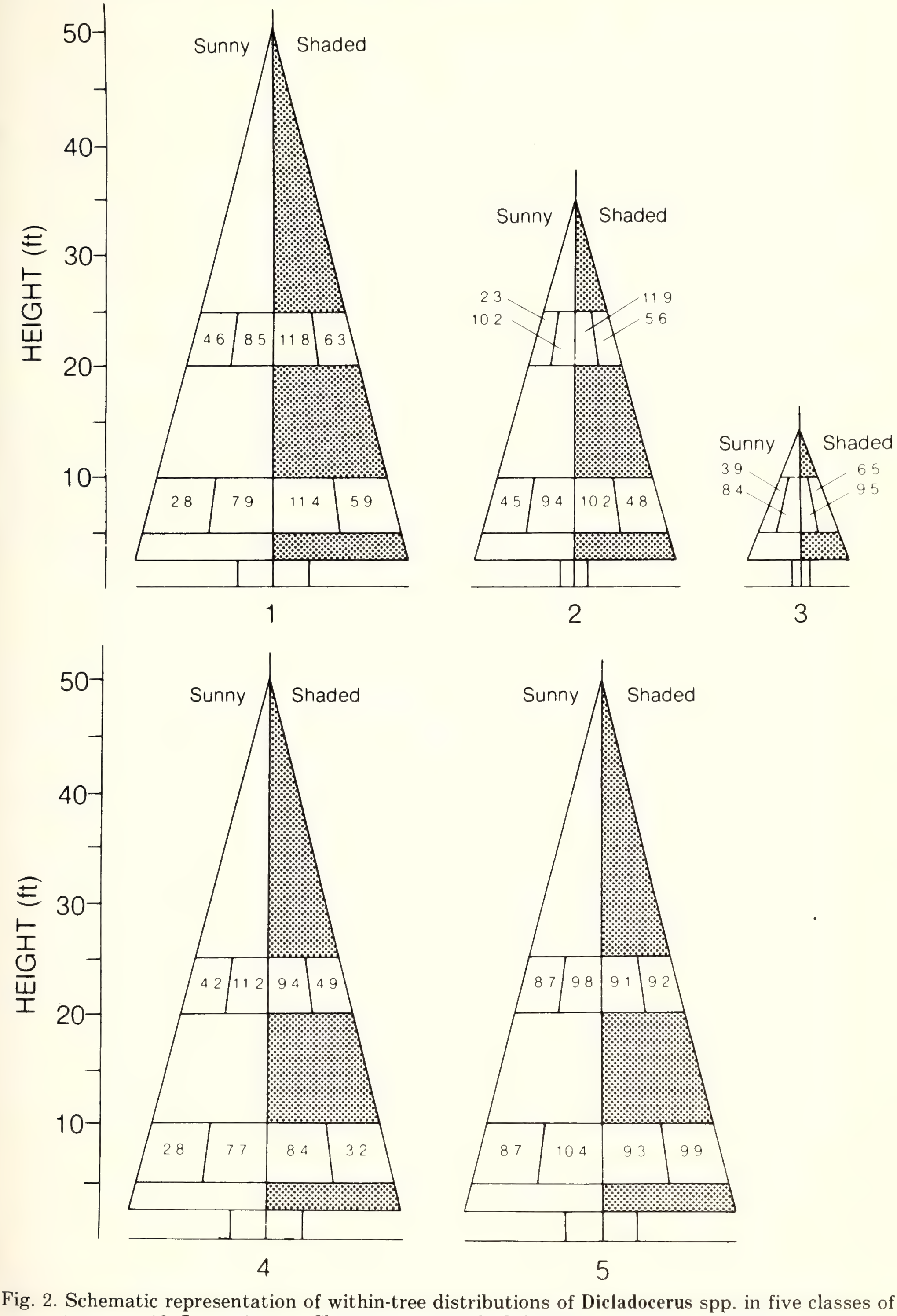

Fig. 2. Schematic representation of within-tree distributions of **Dicladocerus** spp. in five classes of trees on 13 June 1974 at Shoreacres, British Columbia. (Numbers represent percentage parasitism, the outer being those of the outer branch half and the inner those of inner branch half)

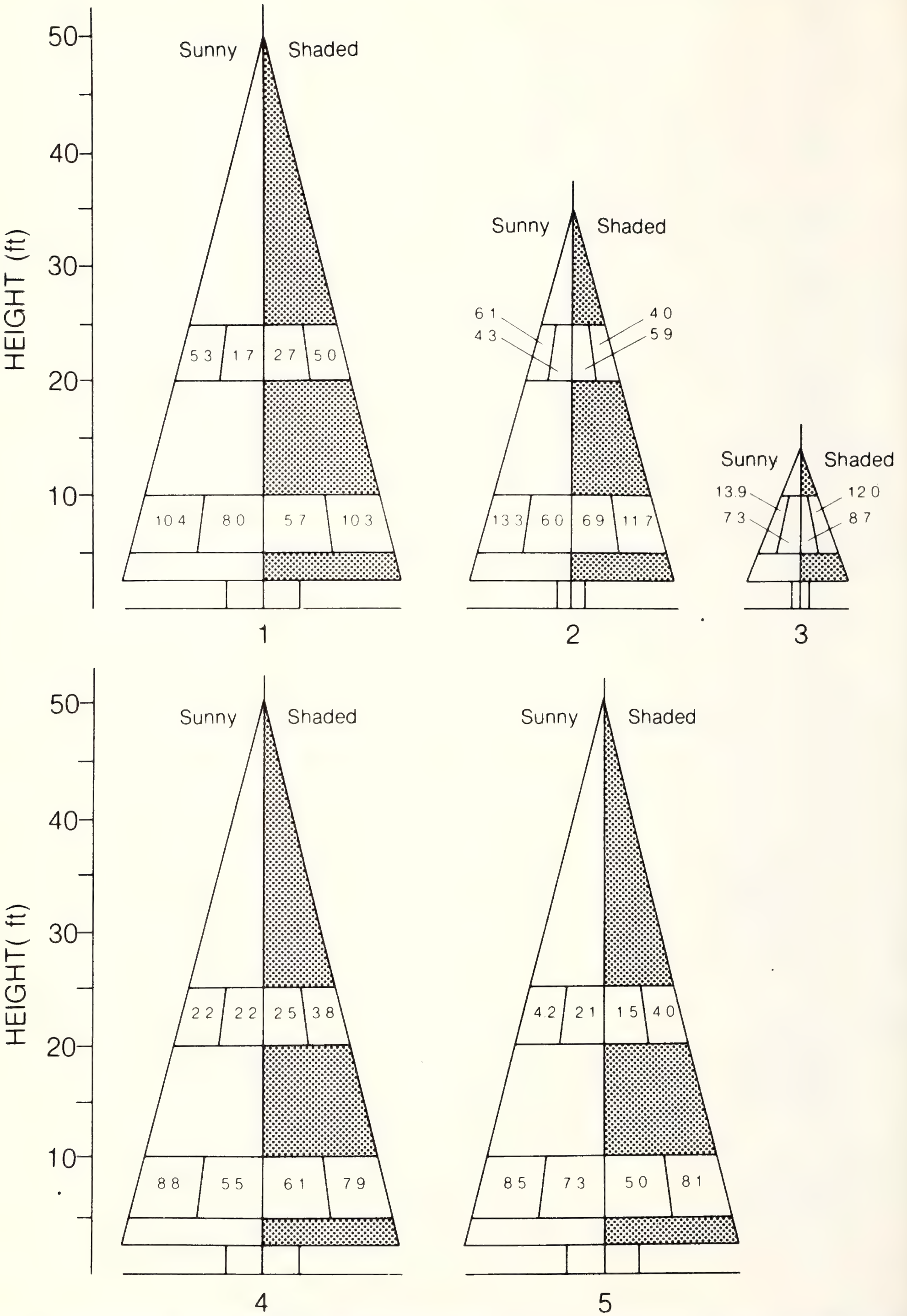

Fig. 3. Schematic representation of within-tree distributions of **Spilochalcis albifrons** in five classes of trees on 13 June 1974 at Shoreacres, British Columbia. (Numbers represent percentage parasitism, the outer being those of the outer branch half and the inner those of the inner branch half)

(Sloan and Coppel 1965; Webb 1953).

The distribution of *Dicladocerus* spp. could be affected by movements of *C. laricella* after parasitization. The amount of spring movement by casebearer larvae is influenced by casebearer density, greater movements occurring at higher densities (Webb 1953). At the densities observed in this study, casebearer movement was not great enough to cause a difference in the distribution of the host between the two collections, the apparent period of parasitization (Miller and Finlayson 1977) in Class 1 trees. Host movement probably is not a factor in the distribution of *S. albifrons* as this species apparently attacks the sessile pupae of the host (Bousfield and Lood 1971).

The within-tree distributions of *Dicladocerus* spp. and *S. albifrons* in Classes 1 and 2 are similar to those in 9.1-12.2 m (30-40 ft.) trees in the western United States (Tunnock *et al.* 1972). The distributions of *Dicladocerus* spp. and *S. albifrons* within trees probably reduces competition for casebearers between these species on open-grown trees (Tunnock *et al.* 1972).

When measuring the degree of parasitism of *C. laricella*, Bousfield and Lood (1971) took their samples from the terminal 45.7 cm (18") of branches rather than whole branches. In open-grown trees more than 7.6 m (25 ft.) high, such a sampling technique would overestimate parasitism by *S. albifrons* and underestimate parasitism by *Dicladocerus* spp.

The differences in distributions of both *C. laricella* and its parasites between classes must be considered when measuring casebearer populations or parasitism, especially if less than whole-branch samples are taken, and when sampling trees of differing types.

ACKNOWLEDGMENTS

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References

Bousfield, W. E. and R. C. Lood. 1971. Impact of parasites on the larch casebearer in the Northern Region 1970. U.S.D.A. For. Serv. Rept. 71-4, Northern Region, Missoula, Mont.

Dixon, W. J. 1973. **BMD Biomedical Computer Programs**. Univ. of Calif. Press, Los Angeles.

Miller, G. E. and T. Finlayson. 1974. Native parasites of the larch casebearer, **Coleophora laricella** (Lepidoptera: Coleophoridae), in the west Kootenay area of British Columbia. J. entomol. Soc. Brit. Colomb. 71: 14-21.

Miller, G. E. and T. Finlayson. 1977. Parasites of the larch casebearer, **Coleophora laricella** (Lepidoptera: Coleophoridae), in the West Kootenay area, British Columbia. J. entomol. Soc. Brit. Columb. (in press).

Sloan, N. F. and H. C. Coppel. 1965. Oviposition patterns and egg predation of the larch casebearer, **Coleophora laricella** Hbn. in Wisconsin. Univ. of Wisconsin For. Res. Note. No. 124.

Tunnock, S., M. McGregor and W. E. Bousfield. 1972. Distribution of larch casebearer parasites in the crowns of western larch trees in the Northern Region. U.S.D.A. For. Serv. Rept. 72-4, Northern Region, Missoula, Mont.

Webb, F. E. 1953. An ecological study of the larch casebearer, **Coleophora laricella** Hbn. (Lepidoptera: Coleophoridae). Ph.D. Thesis, Univ. of Michigan, Ann Arbor, Mich.

Yoshimoto, C. M. 1976. Revision of the genus **Dicladocerus** (Eulophidae: Chalcidoidea) of America north of Mexico, with particular reference to species attacking larch casebearer (Lepidoptera: Coleophoridae). Can. Ent. 108: 1173-1206.

PARASITES OF THE LARCH CASEBEARER, *COLEOPHORA LARICELLA* (LEPIDOPTERA: COLEOPHORIDAE). IN THE WEST KOOTENAY AREA, BRITISH COLUMBIA[1]

GORDON E. MILLER[2] AND THELMA FINLAYSON[2]

ABSTRACT

The parasite complex of the larch casebearer, *Coleophora laricella* (Hbn.), was investigated in the Kootenay area of British Columbia in 1973 and 1974. Forty-one species of hymenopterous parasites were obtained from rearings of almost 153,000 final-instar host larvae and pupae. In 1973 and 1974, 31 and 24 species, respectively, were reared, with 14 common to both years. Twenty-nine of these, in 24 genera, were confirmed as larch casebearer parasites by individual rearings and by reports in the literature. No parasites were obtained from eggs, needle-mining larvae, or third-instar case-bearing larvae. The highest total percentage parasitism was 17.7% in 1973 and 24.5% in 1974, both at Rossland. In Collection II the *Dicladocerus* spp. complex comprised 46.0% of the total parasitism in 1973, and 63.8% of the total in 1974; it was the most abundant at four of the eight collecting sites in 1973 and 13 of the 14 sites in 1974. *Spilochalcis albifrons* (Walsh) comprised 32.8% and 23.5% of the total parasitism in the years 1973 and 1974 respectively; it was most abundant at three collection sites in 1973 and at two in 1974. *Mesopolobus* sp. constituted 4.9% of the total in 1973 and 9.9% in 1974. Larch casebearer densities in the first collection in 1973 were highest at Fruitvale and Shoreacres with 150 and 130 cases per 100 fascicles respectively; in 1974, the highest host densities in the first collection were at Kootenay Bay and Fruitvale with 48 and 41 cases per 100 fascicles respectively.

INTRODUCTION

The larch casebearer, *Coleophora laricella* (Hbn.) (Lepidoptera: Coleophoridae), a European species introduced into western North America, is currently a target of biological control efforts. Releases of exotic parasites have been in progress for about 17 years (Denton 1972; Morris and Monts 1972; Ryan and Denton 1973; Ryan *et al.* 1975, 1977).

Turnbull and Chant (1961) argued that the ecology of a pest being considered for a biological control programme should be studied in the area of proposed release prior to the introduction of natural enemies. To determine the identities of parasites and degree of parasitism of *C. laricella* in British Columbia, surveys were carried out in 1973 and 1974. Results of the 1973 survey were reported by Miller and Finlayson (1974).

METHODS

Procedures in 1974 were similar to those used in the 1973 survey and were described by Miller and Finlayson. Samples were taken in 1973 at eight sites: Anarchist Summit, Arrow Creek, Cascade (=Christina Lake), Fruitvale, Rossland, Sheep's Creek, Shoreacres, and Yahk. In 1974 these eight were again investigated plus the following additional six sites: Cranbrook, Johnstone Creek Park, Kootenay Bay, Roosville, Rykerts and Winlaw (Fig. 1). Collection I on May 14-15, 1974, consisted mainly of final-instar larvae and Collection II on June 12-13, mainly of pupae.

Ten trees were sampled in each collection at 1.5 - 3.0 m (5-10 ft.) and at 6.1 - 7.6 m (20-25 ft.) Five primary branches were taken from the full circumference of each tree at each height. Mass-rearing was done in 30.5x61.0x30.5 cm (1x2x1 ft.) cardboard boxes in which the tops had been replaced by 0.2 mm mesh. Individual rearing of larvae and pupae collected at Cascade, Rossland, Sheep's Creek and Shoreacres in 1974 was done in ½ dram vials to which fresh larch needles were supplied as required by the feeding larvae.

Eggs were collected both years from 10 trees at each site and mass-reared in petri dishes. Early larval instars were collected at Rossland and Shoreacres in August and October, 1973. These were mass-reared in approximately the same way as the later instars.

RESULTS

A total of 134,511 *C. laricella* were mass-reared: 102,947 in 1973 and 31,564 in 1974; and 18,300 were reared individually in 1974. In 1974 there were 20,168 casebearers in Collection I and 11,396 in Collection II, whereas

[1]Based on a thesis submitted by the senior author in partial fulfillment of an M.Sc. degree.

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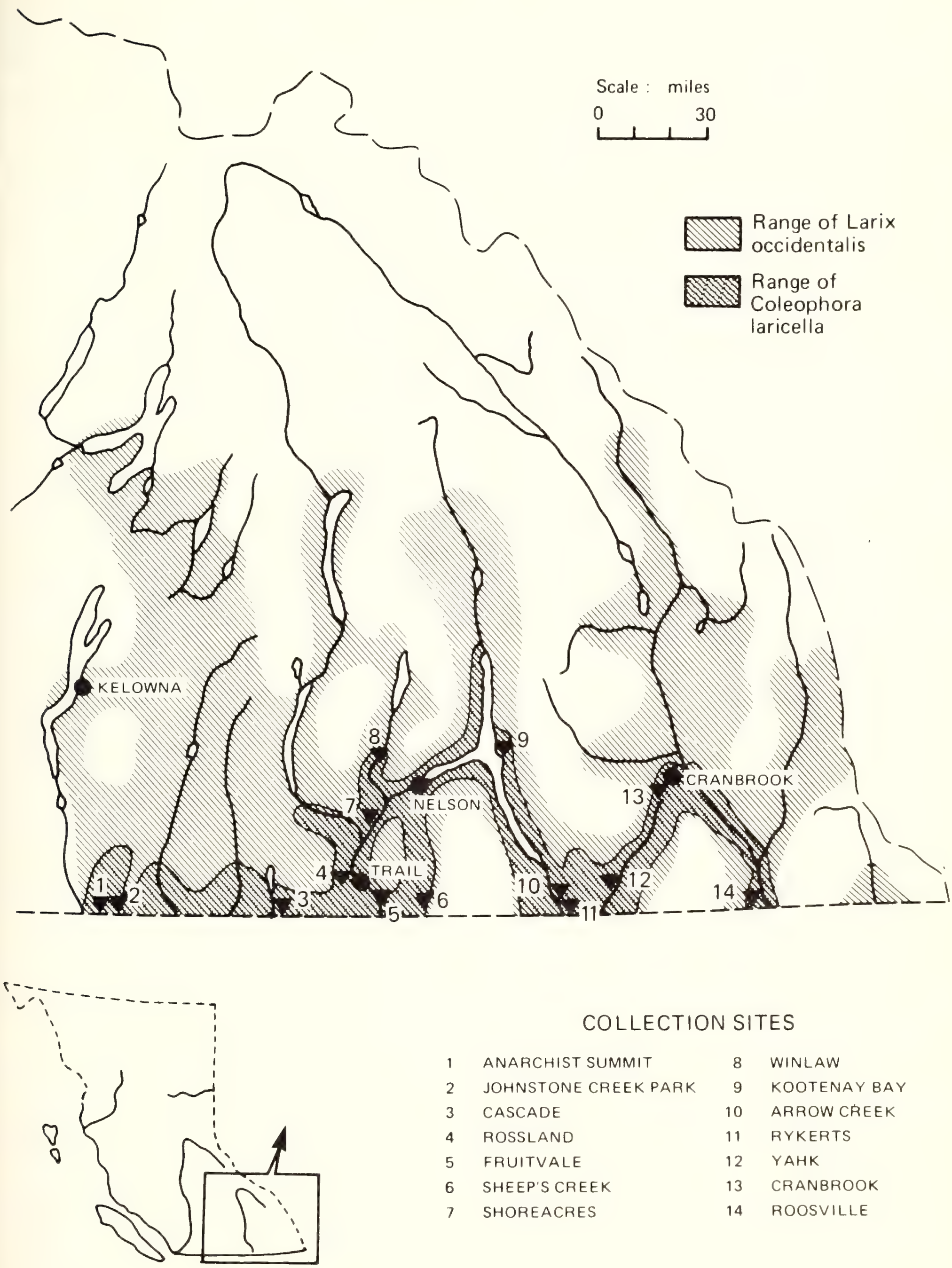

Fig. 1. Distribution of **Coleophora laricella** in British Columbia in 1972 and location of the collection sites in 1973 and 1974. (Adapted from R. F. Shepherd and D. A. Ross, "Problem analysis: larch casebearer in B.C." Unpublished Internal Report BC-37, Pac. For. Res. Cent., Victoria, B.C. 1973).

the comparable collections in 1973 amounted to 40,695 and 62,242. As more samples were taken in 1974 than in 1973, the figures indicate a considerable reduction in populations over the range of this species in British Columbia between the two years.

In 1974, a total of 1,989 specimens of 24 species of hymenopterous parasites and hyperparasites were reared as compared with 4,459 specimens of 31 species in 1973 (Miller and Finlayson 1974). The total number of species obtained in the two years was 41, with 14 common to both.

Table 1. Confirmed parasites from mass-rearings of **Coleophora laricella** in British Columbia in 1973 and 1974

	Abundance							
	1973				1974			
	May 8-9		May 23-25		May 14-15		June 12-13	
Hymenopterous Parasites	No. Obtained	No. Sites[a]	No. Obtained	No. Sites[a]	No. Obtained	No. Sites[b]	No. Obtained	No. Sites[b]
Braconidae								
Bracon pygmaeus Prov.[1,2,3]	32	5	273	8	9	5	6	4
Ichneumonidae								
Campoplex rufipes Prov.[3]							2	1
Diadegma sp.[1,3]					3	2	1	1
Gelis tenellus (Say)[1,2,3]			2	2			2	2
Gelis sp.[1,2,3]			9	4			3	2
Itoplectis vesca Townes[1]			1	1			2	1
Pristomerus sp.[1,2]			2	1	4	4	4	3
Scambus decorus Walley[1]			10	2	4	2	2	1
Eulophidae								
Achrysocharella sp.[1,2]			30	3	7	2	3	1
Chrysocharis laricinellae (Ratz.)[1,3]			5	2			1	1
Cirrospilus pictus (Nees)[3]			1	1				
Dicladocerus spp. (2)[1,2,3]	325	8	1,480	8	693	14	669	14
Elachertus proteoteratis (How.)[3]			1	1				
Euderus cushmani (Crawford)[3]			2	1				
Eulophus sp.[3]*	2	1	2	1				
Tetrastichus dolosus (Gahan)[2]			9	2				
Tetrastichus ecus Wlkr.[1,2]			142	5			1	1
Zagrammosoma americanum Gir.[2]			10	1			2	1
Encyrtidae								
Copidosoma sp.[3]					1	1		
Pteromalidae								
Catolaccus aeneoviridis (Gir.)[2,3]			2	1				
Habrocytus phycidis Ashm.[2,3]	1	1	5	2				
Mesopolobus sp.[1,2]	15	2	158	6	111	9	104	9
Chalcididae								
Spilochalcis albifrons (Walsh)[1,2,3]			1,054	6			247	7
Eurytomidae								
Eurytoma sp.[3]*					1	1		
Diapriidae								
Telenomus spp. (3)[3]*			6	2				
Trissolcus sp.[3]*			10	2				

a-out of 8 b-out of 14
1 confirmed by individual rearings in this study
2 confirmed by Bousfield and Lood (1973)
3 confirmed by Webb (1953)
* confirmed to genus only.

Table 2. Relative abundance of the confirmed **Coleophora laricella** parasite species obtained from mass-rearings of **C. laricella** in British Columbia in 1973 and 1974 (in per cent)

Species	1973 May 8-9	1973 May 23-25	1974 May 14-15	1974 June 12-13
Dicladocerus spp.	86.7	46.0	83.2	63.8
Spilochalcis albifrons		32.8		23.5
Bracon pygmaeus	8.5	8.5		0.6
Mesopolobus sp.		4.9	13.3	9.9
Tetrastichus ecus		4.4		0.1
Other (no. of species)	4.8 (3)	3.3 (19)	3.5 (7)	2.1 (12)

Some of the parasites that emerged from mass-reared samples could have come from hosts other than *C. laricella* that were accidentally included in the collections. A mass-reared parasite was considered to have come from *C. laricella* only if it had been obtained from the individual rearings in this work, or had been verified previously (Bousfield and Lood 1973; Denton 1972; Sloan 1965; Webb 1953).

Twenty-nine species have been confirmed as parasites of *C. laricella* (Table 1). The 12 species not considered to be casebearer parasites are: *Aphidius* sp. (Aphidiidae); *Acrolyta* sp., *Hyposoter* sp. (Ichneumonidae); *Aprostocetus* spp. (2), *Diglyphus* sp., *Melittobia* sp. (Eulophidae); *Thysanus* sp. (Thysanidae); *Cyrtogaster vulgaris* Wlkr. (Pteromalidae); *Aphanogmus* sp. (Ceraphronidae); and *Aclista* sp. (Diapriidae).

Most of the confirmed species represent new host records for British Columbia. *Gelis tenellus* (Say), *Scambus decorus* Wly., *Tetrastichus ecus* Wlkr. [=*xanthops* (Ratz.)] and *Spilochalcis albifrons* (Walsh) were previously recorded by Andrews and Geistlinger (1969). These workers also obtained *Bracon* sp. which may well have been *B. pygmaeus* Prov; *Amblymerus* sp. which probably is the same as the *Mesopolobus* sp. found in this study; and a species reported as *Dicladocerus westwoodii* Westw. which may be either of the two new species found in this study, *D. nearcticus* Yosh. or *D. pacificus* Yosh. (Yoshimoto 1976). Two species not taken in the study but which have been reported previously as parasites of *C. laricella* in British Columbia are *Scambus transgressus* (Holmg.) and *Sceptrothelys deione* (Wlkr.) (Andrews and Geistlinger 1969).

Although many parasite species were obtained, only a few predominated, with *Dicladocerus* spp. and *S. albifrons* being by far the most abundant (Table 2). The most abundant species were also the most widespread (Table 1). *Dicladocerus* spp. and *Mesopolobus* sp. increased in relative abundance in 1974 when compared with 1973, while the other species that were relatively abundant in 1973

Table 3. Summary of confirmed parasites from mass-rearings of **Coleophora laricella** collected at 14 locations in British Columbia on May 14-15, 1974

Location	C. laricella No. of Cases	C. laricella Cases/100 Fascicles	Dicladocerus spp. No. Emerged	Dicladocerus spp. %	Mesopolobus sp. No. Emerged	Mesopolobus sp. %	Other No. Reared	Other %	Total No. Reared	Total No. of Taxa	Total %
Anarchist Summit	95	1.2	1	1.1					1	1	1.1
Arrow Creek	2,126	29.8	36	1.7	9	0.4	3	0.1	48	2	2.3
Cascade	1,488	17.7	61	4.1	9	0.6	8	0.5	78	7	5.2
Cranbrook	53	0.6	3	5.7					3	1	5.7
Fruitvale	2,774	40.8	86	3.1	11	0.4	11	0.4	108	5	3.9
Johnstone Creek Park	169	8.5	2	1.2					2	1	1.2
Kootenay Bay	4,275	47.8	9	0.2	4	0.1	5	0.1	18	2	0.4
Roosville	61	0.7	3	4.9					3	1	4.9
Rossland	832	8.0	54	6.5	3	0.4	9	1.1	66	4	7.9
Rykerts	4,619	27.5	162	3.5	27	0.6	3	0.1	192	2	4.2
Sheep's Creek	1,873	19.7	121	6.5	31	1.7	19	1.0	171	5	9.1
Shoreacres	1,604	25.4	150	9.4	18	1.2	13	0.8	181	6	11.3
Winlaw	94	1.2	4	4.3	1	1.1			5	2	5.3
Yahk	105	0.8	1	1.0			1	1.0	2	1	1.9

Table 4. Summary of confirmed parasites from mass-rearings of **Coleophora laricella** collected at 14 locations in British Columbia on June 12-13, 1974

Location	C. laricella		Parasitism										
			Dicladocerus spp.		**Mesopolobus sp.**		**Spilochalcis albifrons**		Other		Total		
	No. of Cases	Cases/100 Fascicles	No. Emerged	%	No. Emerged	%	No. Emerged	%	No. Reared	%	No. Reared	No. of Taxa	%
Anarchist Summit	94	0.9	5	5.3					1	1.1	6	2	6.4
Arrow Creek	1,546	18.1	97	6.3	11	0.7	12	0.8	8	0.5	128	3	8.3
Cascade	1,199	10.5	53	4.4	9	0.8	60	5.0	5	0.4	127	8	10.6
Cranbrook	38	0.4	2	5.3							2	1	5.3
Fruitvale	1,615	26.1	71	4.4	11	0.7	12	0.7	5	0.3	98	6	6.1
Johnstone Creek Park	115	5.0	4	3.5							4	1	3.5
Kootenay Bay	2,024	36.0	62	3.1					3	0.1	65	2	3.2
Roosville	56	0.7	1	1.8							1	1	1.8
Rossland	147	3.9	23	15.6	2	1.4	6	4.1	5	3.4	36	2	24.5
Rykerts	1,720	18.1	123	7.2	24	1.4	14	0.8	6	0.3	167	3	9.7
Sheep's Creek	1,001	9.4	97	9.7	18	1.8	19	1.9	17	1.7	151	6	15.1
Shoreacres	1,724	15.1	124	7.2	27	1.6	124	7.2	12	0.7	287	8	16.6
Winlaw	75	0.8	5	6.7	1	1.3					6	1	8.0
Yahk	42	0.3	2	4.8	1	2.4					3	1	7.1

decreased, relatively. In 1974, *Dicladocerus* spp. were the most abundant at all locations in the first collection (Table 3) and at 13 in the second (Table 4). In 1973, *Dicladocerus* spp. were the most abundant at six of the eight locations in the first collection and at five in the second collection; *B. pygmaeus* was the most abundant at two in the first collection and one in the second; and *S. albifrons* was the most abundant at two in the second (Miller and Finlayson 1974).

Greater parasitism, in terms of both number of taxa and percentage parasitism, occurred in the second collection than in the first in both 1973 (Miller and Finlayson) and 1974 (Tables 1, 3, 4).

The greatest casebearer densities per 100 fascicles in 1974 were at Kootenay Bay and Fruitvale where there were, respectively, 47.8 and 40.8 in the first collection and 36.0 and 26.1 in the second (Tables 3, 4). The greatest total percentage parasitism of 24.5% occurred at Rossland where host density was 3.9 casebearers per 100 fascicles. Percentages of parasitism at the various locations were not related to host densities, as was also the case in 1973 (Miller and Finlayson 1974).

Achrysocharella sp. was the only gregarious parasite species indicated by individual rearings. The mean number of adults produced from four cases was 3.25. Bousfield and Lood (1971) also found a very low incidence of gregariousness. However, they found three species, *Achrysocharella silvia* Gir., *T. ecus* and *Mesopolobus* sp., that occasionally produced more than one adult per case.

No parasites emerged from mass-rearings of 2,427 eggs, 19,279 needlemining larvae, or 6,890 fall-collected, casebearing, third-instar larvae.

DISCUSSION

The parasite complex and incidence of parasitism on *C. laricella* in British Columbia were comparable to those in other areas of North America (Bousfield and Lood 1971, 1973; Denton 1972; Sloan 1965; Webb 1953). The parasite complex also resembles the complexes in the Alps region of Europe (Jasch 1973), although more major species, in terms of relative abundance and constancy, occurred in the Alps. There was a low incidence of three species of parasites in needle-mining larvae and casebearing, third-instar larvae in the Alps, whereas no parasites were taken from these stages in British Columbia. There are no reports of parasites that emerge from *C. laricella* eggs.

Miller and Finlayson (1974) reported two European species that had been released against *C. laricella* in eastern North America in the 1930's: *Chrysocharis laricinellae* (Ratz.) and *Cirrospilus pictus* (Nees). *C. laricinellae* was found again in 1974. Ryan *et al.* (1974) give possible explanations for the presence of these species.

Agathis pumila (Ratz.) (Braconidae) is conspicuous by its absence in this survey. It was released against *C. laricella* in British Columbia in 1969 and has since become established (Morris and Monts 1972). One of the release sites was less than one mile from the Arrow Creek location in this study.

The increase in parasitism between the two collections in both 1973 and 1974 indicates that adult parasites are active during this period and/or that *C. laricella* reaches a more susceptible stage. Sweep-net collections of adults of *B. pygmaeus, I. vesca, Dicladocerus* spp. and *Mesopolobus* sp. during the first 1974 collection confirmed their presence in the field during this period. The increase in parasitism by *S. albifrons* between collections was probably correlated with the increase in host pupal populations between collections, as pupae are thought to be the stage attacked by this species (Bousfield and Lood 1971). Similar increases in parasitism of *C. laricella* and other coleophorids during the spring-feeding period have been reported (Beacher 1947; Bousfield and Lood 1971; Doner 1934).

Mortality of *C. laricella* caused by the native parasites may be limited by the number of alternate hosts available to the parasites in the absence of suitable instars of *C. laricella* as these, or related species, are known to have more than one generation per year (Clausen 1962; Dowden 1941; Jasch 1973) and not all of them can be spent on *C. laricella*. *S. albifrons* is more dependent on alternate hosts than other species as very few females (2.5% of the species total in 1973 and 0.0% in 1974) emerged from *C. laricella* in this study.

A positive trend was noted between total percentage parasitism and the total number of lepidopteran and sawfly larvae (which may or may not be alternate hosts of the parasites taken) at five of the sites. In eastern Canada the introduced species *C. laricinellae,* is much more effective against *C. laricella* in the presence of *A. pumila* or in the presence of alternate hosts due to improved synchronization (Quednau 1970). The lack of alternate hosts has been suggested as a limiting factor of parasitism in other coleophorids (Beacher 1947; Doner 1934, 1936).

Species of exotic parasites that have been recently released, or that are contemplated for release, against *C. laricella* in western North America are taxonomically related to the native species reared in this study. They also are non-specific and non-synchronized with *C. laricella* (with the exception of *A. pumila*) and have a minor role in reducing larch casebearer populations in Europe (Jasch 1973). For these

reasons, the probability that they will be effective biological control agents in western North America is questionable.

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References

Andrews, R. J. and N. J. Geistlinger. 1969. Parasites of the larch casebearer, **Coleophora laricella** (Hbn.), in British Columbia (Lepidoptera: Coleophoridae). J. entomol. Soc. Brit. Columb. **66:** 50-51.

Beacher, J. H. 1947. Studies of pistol case-bearer parasites. Ann. ent. Soc. Am. **40:** 530-544.

Bousfield, W. E. and R. C. Lood. 1971. Impact of parasites on the larch casebearer in the Northern Region 1970. U.S.D.A. For. Serv. Rept. 71-4, Northern Region, Missoula, Mont.

Bousfield, W. E. and R. C. Lood. 1973. Parasites of the larch casebearer in Montana, Idaho, and Washington. Environ. Ent. 2: 212-213.

Clausen, C. P. 1962. **Entomophagous Insects.** Hafner Publ. Co., New York.

Denton, R. E. 1972. Establishment of **Agathis pumila** (Ratz.) for control of larch casebearer, and notes on native parasitism and predation in Idaho. U.S.D.A. For. Serv. Res. Note INT-164, Intermt. For. and Range Exp. Stn.

Doner, M. H. 1934. Observations on the biology of **Microbracon pygmaeus** (Prov.), an important parasite of **Coleophora pruniella** Cl. Ann. ent. Soc. Am. **27:** 435-442.

Doner, M. H. 1936. Hymenopterous parasites of **Coleophora pruniella** CL., and parasites recorded from other species of **Coleophora.** Ann. ent. Soc. Am. **29:** 224-244.

Dowden, P. B. 1941. Parasites of the birch leaf-mining sawfly (**Phyllotoma nemorata**). U.S.D.A. Tech. Bull. 757.

Jasch, A. 1973. Populationsdynamik und Parasitenkomplex der Lärchenminiermotte, **Coleophora laricella** Hbn., im natürlichen Verbreitungsgebiet der Europäischen Lärche, **Larix decidua** Mill. Z. angew. Ent. **73:** 1-42.

Miller, G. E. and T. Finlayson. 1974. Native parasites of the larch casebearer, **Coleophora laricella** (Lepidoptera: Coleophoridae), in the west Kootenay area of British Columbia. J. entomol. Soc. Brit. Columb. **71:** 14-21.

Morris, E. and J. Monts. 1972. Larch casebearer infestations in Nelson Forest District, 1972. Can. For. Serv., Forest Insect & Disease Surv. Pest Rept., Pacific Forest Research Centre, Victoria, B.C.

Quednau, F. W. 1970. Competition and cooperation between **C. laricinellae** and **A. pumila** on larch casebearer in Quebec. Can. Ent. **102:** 602-612.

Ryan, R. B., W. E. Bousfield, R. E. Denton, R. L. Johnsey, L. F. Pettinger and R. F. Schmitz. 1975. Additional releases of larch casebearer parasites for biological control in the western United States. U.S.D.A. For. Serv. Res. Note PNW-242.

Ryan, R. B., W. E. Bousfield, C. W. Johanningmeier, G. B. Parsons, R. F. Schmitz and L. J. Theroux. 1977. Releases of recently imported larch casebearer parasites for biological control in the western United States, including relocations of **Agathis pumila.** U.S.D.A. For. Serv. Res. Note PNW-290.

Ryan, R. B., W. E. Bousfield, G. E. Miller and T. Finlayson. 1974. Presence of **Chrysocharis laricinellae**, a parasite of the larch casebearer, in the Pacific Northwest. J. econ. Ent. **67:** 805.

Ryan, R. B. and R. E. Denton. 1973. Initial releases of **Chrysocharis laricinellae** and **Dicladocerus westwoodii** for biological control of the larch casebearer in the western United States. U.S.D.A. For Serv. Res. Note PNW-200.

Sloan, N. F. 1965. Biotic factors affecting populations of the larch casebearer **Coleophora laricella** Hbn. in Wisconsin. Ph.D. Thesis, Univ. of Wisconsin, Madison, Wisc.

Turnbull, A. L. and D. A. Chant. 1961. The practice and theory of biological control of insects in Canada. Can. J. Zool. **39:** 697-753.

Webb, F. E. 1953. An ecological study of the larch casebearer, **Coleophora laricella** Hbn. (Lepidoptera: Coleophoridae). Ph.D. Thesis, Univ. of Michigan, Ann Arbor, Mich.

Yoshimoto, C. M. 1976. Revision of the genus **Dicladocerus** (Eulophidae: Chalcidoidea) of America north of Mexico, with particular reference to species attacking larch casebearer (Lepidoptera: Coleophoridae). Can. Ent. **108:** 1173-1206.

FEEDING POTENTIAL OF PREDATORS OF *MYZUS PERSICAE*[1]/

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ABSTRACT

A rate of feeding for predator insects on th green peach aphid, *Myzus persicae* (Sulzer), was determined based on the number of aphids consumed from a more natural environment corrected for reproduction and natural death. Of the predator species studied, the largest, *Coccinella transversoguttata* Falderman, consumed about 10 times more aphids than the smallest, *Orius tristicolor* (White), and about 7 times more than the average for all other predator species combined.

INTRODUCTION

Pest management specialists working in the Yakima Valley of central Washington have needed a method of relating the abundance of certain predator insects to their potential effect on populations of the green peach aphid (GPA), *Myzus persicae* (Sulzer). A predictive model was therefore developed whereby the numerical census of a predator species is converted to factors that reflect the reductive impact of the predator complex against the GPA (Tamaki et al. 1974). Thus, one component of this model separates the predator complex into discrete groups, each with gross similarities in feeding capacity. Then each group is assigned a numerical factor related to its rate of consumption of aphids. The feasibility of the model was demonstrated by using factors drawn from date provided by Goodarzy and Davis (1958) and Simpson and Burkhardt (1960), concerning the predators of the spotted alfalfa aphid, *Therioaphis maculata* (Buckton), for demonstrating the feasibility of the model, but we now needed factors applicable to the predators of the GPA found in the Yakima Valley. However, workers studying aphidophagous predators in the past have usually introduced known number of prey into cage with a predator and then counted the number dead, partially eaten, or missing. Such a procedure cannot provide an accurate estimate of the impact of predators on a viable population of aphids. We therefore altered the procedure by providing a host plant for the aphids when we exposed them to predators so as to incorporate the effects of reproduction of the aphids and natural mortality on the prey searching of the predators. We also examined the apparent role and abundance of predator species in the field.

MATERIALS AND METHODS

In 1973, single adult predators were placed on a bouquet of sugarbeet leaves in 1-pint ice cream carton cages located at random on a laboratory bench under daylight-fluorescent lighting, which provided a 16 h photophase. Then 100 GPA from the laboratory colony (3rd and 4th instars and adults) were placed in each cage. The cages were examined each morning for 3 days (days 2, 3, and 4) after the predators were introduced and the number of aphids was counted. Also, on days 2 and 3, sufficient aphids were added to bring the total in each cage to 100. The smaller species of predators were found to consume only ca. 10 of the aphids/day; the larger species consumed ca. 50. The resulting differences between cages in the age distribution and reproduction of the aphids then produced inconsistent numbers of prey consumed. Therefore, in 1974, we used sugarbeet leaf bouquets and ice cream carton cages as before but reduced the number of aphids available to the smaller predators to 20/day. In this way all species of predators actually consumed about 50% of the prey available. Also, in 1973 and 1974, we noted that reproduction and natural mortality of the aphids began to be affected by the deterioration of the bouquets by the 4th day of the test. Therefore, in 1975, the aphids were placed on small sugarbeet plants in large plastic cages (Fig. 1). Otherwise (numbers of aphids per cage per day), the procedure was like that in 1974.

The insect predators used in the test were collected in the field from sugarbeet, clover, or alfalfa. Three species (determined by availability) were tested each week through the growing season.

Temperatures during the test period averaged 24°C (range of 19-33°C); the RH averaged 46% (range 44-48%). Rate of predation was determined as the average of the difference between the number of aphids available at the beginning of each day minus the number remaining after each day for 4 days. Each treatment was replicated 10 times on each of the 4 days.

RESULTS AND DISCUSSION

Although the difference in the test procedures in 1974 and 1975 resulted in differences

[1]/ Hemiptera: Aphididae.

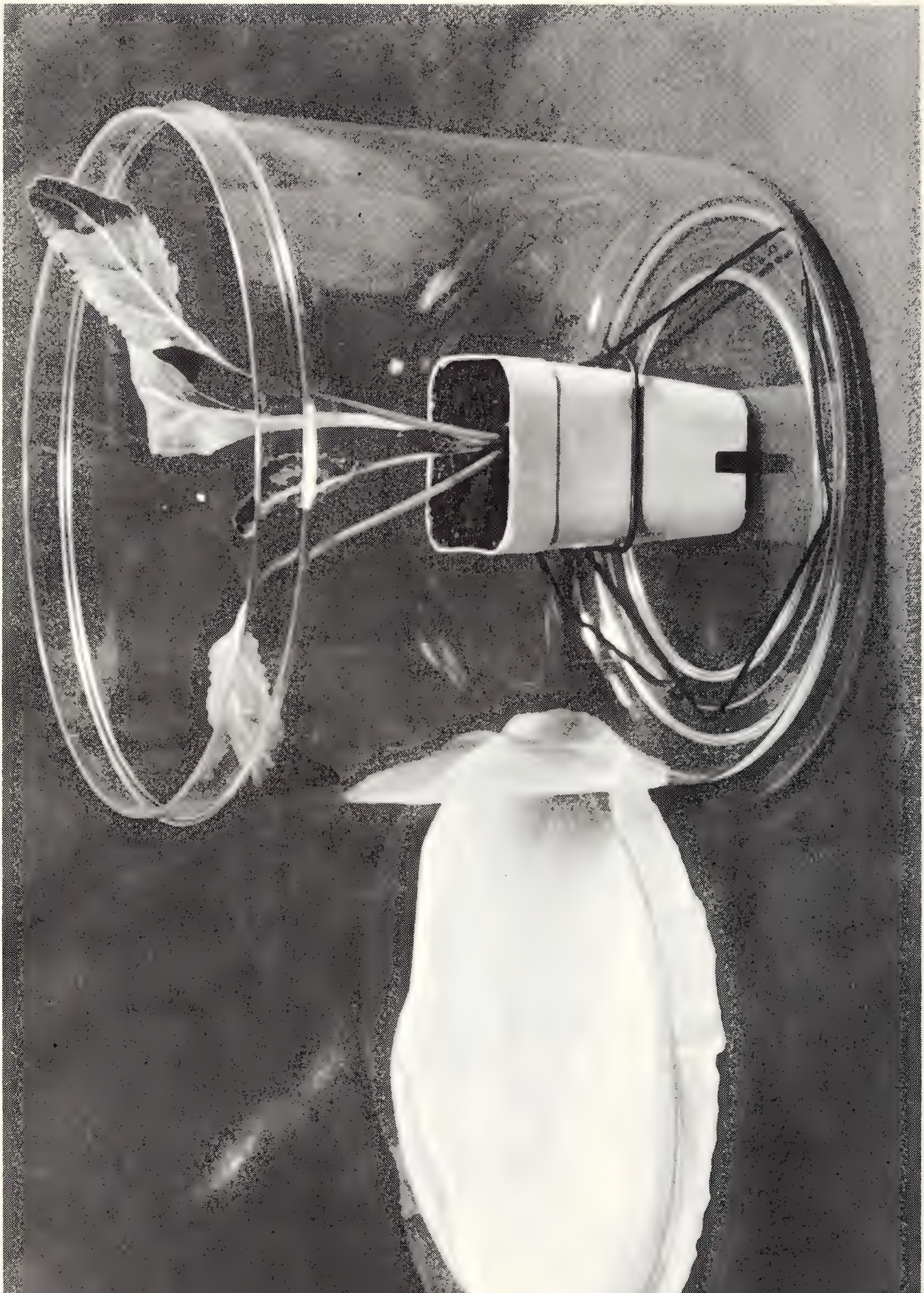

Fig. 1. Cage used to isolate predator and aphids on sugarbeet plant.

in aphid reproduction and natural death, the feeding rate for a given species of predator was similar both years; therefore, these data were combined in Table 1. Also, the data for the 2 *Bembidion* spp. were combined because only small numbers were tested and the feeding rates were very similar. Plainly, the size of the predator was of major importance. Thus, the daily consumption of GPA by *Coccinella transversoguttata*, the largest of the predators studied, was 10 times that of the smallest predator, *Orius tristicolor*, 5 times that of the combined average of all the other predator species listed in Table 1.

In the field, *C. transversoguttata*, one of the large coccinellid species, was more common than *Hippodamia convergens* Guérin-Méneville. *Nabis alternatus* was more common sugarbeets, alfalfa, and clover than *N. americoferus* Carayon though the latter was found frequently in these crops. *Geocoris bullatus*, which is larger than *G. pallens*, consumed ca. 2 more aphids/day. However, *G. pallens* was the most abundant in sugarbeets and potatoes; *G. bullatus* generally inhabits more permanent grass covers such as floors of orchards and also many perennial forage crops (Tamaki 1972). Little is known of *Scymnus marginicollis* except that we have frequently observed the larvae and adults of this small coccinellid feeding on GPA on sugarbeets.

Table 1. Average rate of predation of green peach aphid by selected adult predators.

Species	No. of predators	Mean (± se) predation/day per predator
Coccinella transveroguttata Falderman	70	52.70 ± 3.43
Nabis alternatus Parshley	100	10.37 ± .62
Anthocoris melanocerus Reuter	50	8.46 ± .74
Geocoris bullatus (Say)	80	8.30 ± .57
Scymnus marginicollis Mann	90	7.99 ± .43
Bembidion spp.	40	6.66 ± .67
Geocoris pallens Stal	80	6.47 ± .52
Orius tristicolor (White)	90	5.31 ± .43

The two small carabids, *Bembidion obscurellum* Mots. and *B. rupicola* Kby., were abundant in some fields of sugarbeets and potatoes. In the laboratory, these species will feed on larval scab gnat, *Pnyxia scabiei* (Hopkins), and GPA. Mitchell (1963) reported that the crop contents of *Bembidion lampros* (Herbst) consisted of parts of collembolans, small mites, and earthworm material and that in the laboratory, the adults and larvae would feed on most types of invertebrate animal prey found in soil samples.

Anthocoris melanocerus Reuter and *Orius tristicolor* are in the same family, Anthocoridae, but *A. melanocerus* is ca. 4-5 times larger than *O. tristicolor* and consumed nearly twice as many GPA. *A. melanocerus* is primarily known as a predator of psyllids on deciduous fruit trees (Madsen 1961 and Watson and Wilde 1963); however, it has also been reported feeding on aphids on many vegetable and forage crops (Tamaki and Weeks 1968). *Orius tristicolor* was rarely observed to feed on aphids in the field; in fact, it was seen to run between aphids in attempts to capture a thrip. Smith and Hagen (1956) also reported that *O. tristicolor* preferentially fed upon mites and thrips, rarely aphids. In the laboratory, however, *O. tristicolor* will feed on aphids if no other prey is available.

Although the feeding rates of the predators that we report are based on laboratory studies, most of these predators (except *O. tristicolor* and *Bembidion* spp.) would probably feed at the same rates in the field if aphids were abundant. However, when aphid numbers are minimum, searching time and prey preference would probably lower the rates.

Predators of *Myzus persicae*
Anthocoris melanocerus
Bembidion spp.
biological control
Coccinella transversoguttata
Geocoris bullatus
Geocoris pallens
insect predators
Myzus persicae - green peach aphid
Nabis alternatus
Orius tristicolor
Scymnus marginicollis

References

Goodarzy, K., and D. W. Davis. 1958. Natural enemies of the spotted alfalfa aphid in Utah. J. Econ. Entomol. 51: 612-6.

Madsen, H. F. 1961. Notes on **Anthocorus melanocerus** Reuter (Hemiptera: Anthocoridae) as a predator of the pear psylla in British Columbia. Can. Entomol. 93: 660-2.

Mitchell, B. 1963. Ecology of the two carabic beetles, **Bembedion lampros** (Herbst) and **Trechus quadristriatus** (Shrank). I. Life cycles and feeding behavior. J. Anim. Ecol. 32: 289-99.

Simpson, R. G., and C. C. Burkhardt. 1960. Biology and evaluation of certain predators of **Therioaphis maculata** (Buckton). J. Econ. Entomol. 53: 89-94.

Smith, R. F., and K. S. Hagen. 1956. Enemies of spotted alfalfa aphid. Calif. Agric. 10: 8-10.

Tamaki, G. 1972. The biology of **Geocoris buttalus** inhabiting orchard floors and its impact on **Myzus persicae** on peaches. Environ. Entomol. 1: 559-65.

Tamaki, G., J. U. McGuire, and J. E. Turner. 1974. Predator power and efficacy: A model to evaluate their impact. Environ. Entomol. 3: 625-30.

Tamaki, G., and R. E. Weeks. 1968. **Anthocoris melanocerus** as a predator of the green peach aphid on sugarbeets and broccoli. Ann. Entomol. Soc. Am. 61: 579-84.

Watson, T. K., and W. H. A. Wilde. 1963. Laboratory and field observations of two predators of pear psylla in British Columbia. Can. Entomol. 95:435-8.

THE SYSTEMATIC POSITION OF THE APPLE-AND-THORN SKELETONIZER:

This moth, also known as squeletteuse du pomier et du cenellier (Benoit 1975), has been referred to in North America as *Anthophila pariana* (Cl.) since the 1930's and usually as *Hemerophila pariana* (Cl.) before then. To check its identity in Western Canada the genitalia and the external morphology of specimens from the Vancouver, B.C., area were compared with data in European studies on the taxonomy and systematics. It was confirmed that the species found in the Vancouver district, where it was usually abundant in 1976, is a single species rather than a complex and is the same species found in Europe and the USSR; but that, in line with the conclusions of Danilevsky (1963) and Danilevsky and Kuznetzov (1973), it is of the genus *Hemerophila* Hübn. rather than of *Anthophila* Haw. The correct name of the species found in the Vancouver district, and presumably elsewhere in North America, is therefore *Hemerophila pariana* (Cl.). - *M. Doganlar*, Pestology Centre, Simon Fraser University, Burnaby, B.C.

References

Benoit, P. 1974. Noms Francais d'Insectes au Canada. Agric. Que. publ. QA38-R4-30.

Danilevsky, A. S. 1963. [new species of Glyphipterygidae (Lepidoptera) in the USSR] Ent. Rev. 48: 585-593.

Danilevsky, A. S., and V. I. Kuznetzov. 1973. [A review of the Glyphipterygid moths of the genus **Hemerophila** Hb. (Lepidoptera, Glyphipterygidae) of the fauna of the USSR]. Tr. Vsesoyuz. Entomol. Obshch. 56: 8-17.

MORPHOLOGY OF ALIMENTARY AND REPRODUCTIVE TRACTS OF THE RODENT BOT FLY, *CUTEREBRA TENEBROSA* (DIPTERA: CUTEREBRIDAE)[1]

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and
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ABSTRACT

The internal reproductive and alimentary structures of *Cuterebra tenebrosa* Coquillett were studied and compared to other calypterate flies. Well defined mouth parts are present. Paired lingual salivary glands extend horizontally almost to the abdomen; however, labial salivary glands were not found. The alimentary canal is complete in female flies, whereas males lack a crop. Females have three spherical spermathecae opening into the upper portion of the genital chamber. Male reproductive structures are similar to those in other flies. Tracheal air sacs fill one-third to one-half of the abdomen.

INTRODUCTION

Little is known concerning the internal structure of *Cuterebra* bot flies. Townsend (1935) provided the earliest descriptions of *Cuterebra* alimentary and reproductive tracts but did not include illustrations.

In 1963, Catts described and illustrated the alimentary and reproductive tracts of *Cuterebra latifrons* Coquillett. A comparative study of the alimentary canal of several flies including *C. latifrons* was made by Singh and Judd in 1966. Various authors have described and illustrated the external genitalia of *Cuterebra* (Bennett 1955; Haas & Dicke 1958; Catts 1963; Graham and Capelle 1970; and Baird and Graham 1973). The purpose of the present paper is to report findings from dissections of *Cuterebra tenebrosa* Coquillett specimens and to provide illustrations of the structures.

METHODS AND MATERIALS

Adult flies were obtained by rearing larvae in captive bushytailed wood rats *(Neotoma cinerea Ord.)*. Within five days after emergence, flies were injected with Kahle's solution to kill and fix them in an extended position. They were stored in the same preservative for several days and then transferred to 70% alcohol for permanent storage. Dissections were performed with standard insect dissection tools under a binocular microscope.

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OBSERVATIONS AND DISCUSSION

The use of Kahle's solution to kill adult flies proved a very useful technique since the solution perpeated all body areas and preserved the internal organs very well.

Alimentary Tract

No attempt was made to describe the mouth parts of *C. tenebrosa.* The mouth parts are typically muscoid in both sexes as described for *C. emasculator* (Bennett 1955) and *C. latifrons* (Catts 1963).

The paired racemose salivary glands are connected anteriorly by a common salivary duct which extends to the oral structures (Figure 1). Posteriorly, the glands are situated horizontally in the lower thorax and extend almost to the abdomen. Catts (1963) reported the salivary glands extending only into the prothorax of *C. latifrons.* Singh and Judd (1966), also working with *C. latifrons* found salivary glands extending into the abdomen. Townsend (1935) described salivary glands of *Cuterebra* as being atrophied or absent. These discrepancies may be due to age or to preservation method.

Lowne (1890) and Hewitt (1914) indicated that paired lingual salivary glands of *Calliphora* and *Musca*, respectively, were of a simple tubular type which ultimately terminated in the posterior of the abdomen. Hori (1972) also found tubular salivary glands extending into the abdomen of flies belonging to eight calypterate muscoid families. An additional difference between *Cuterebra* and other muscoid flies was that the labial salivary glands present in *Calliphora* and *Musca* (Lowne 1890; Hewitt 1914) were absent in *Cuterebra.*

The alimentary canal in *C. tenebrosa* is complete and basically similar to that in other muscoid families. An important difference is the apparent absence of a crop in male *C.*

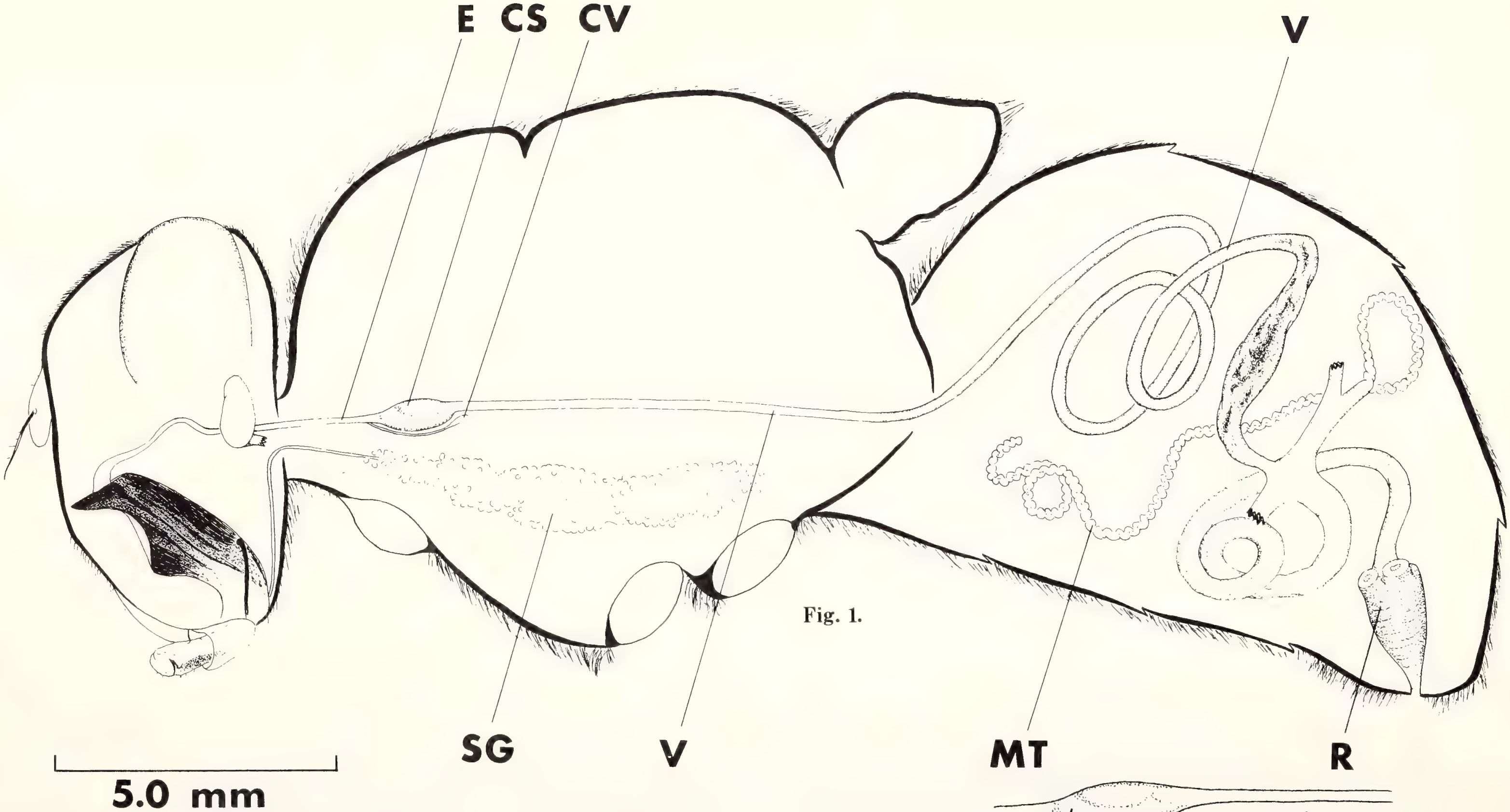


Fig. 1.

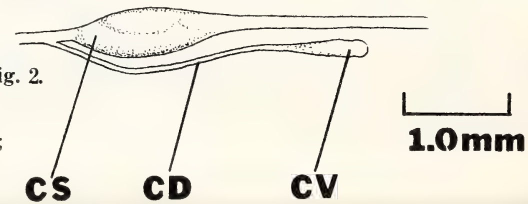
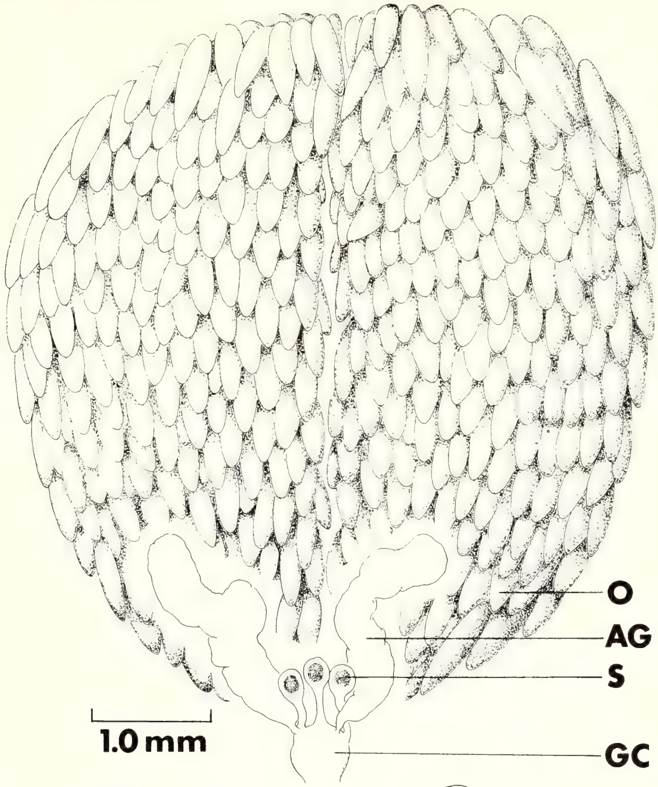


Fig. 2.

Fig. 1. Alimentary tract of **Cuterebra tenebrosa.** E, esophagus; CS, cardiac sac; CV, crop vestige; SG, salivary gland; V, ventriculus; MT, Malphighian tubules; R, rectum

Fig. 2. Enlarged view or cardiac sac. CS, cardiac sac; CD, crop duct; CV, vestigial crop

Fig. 3.



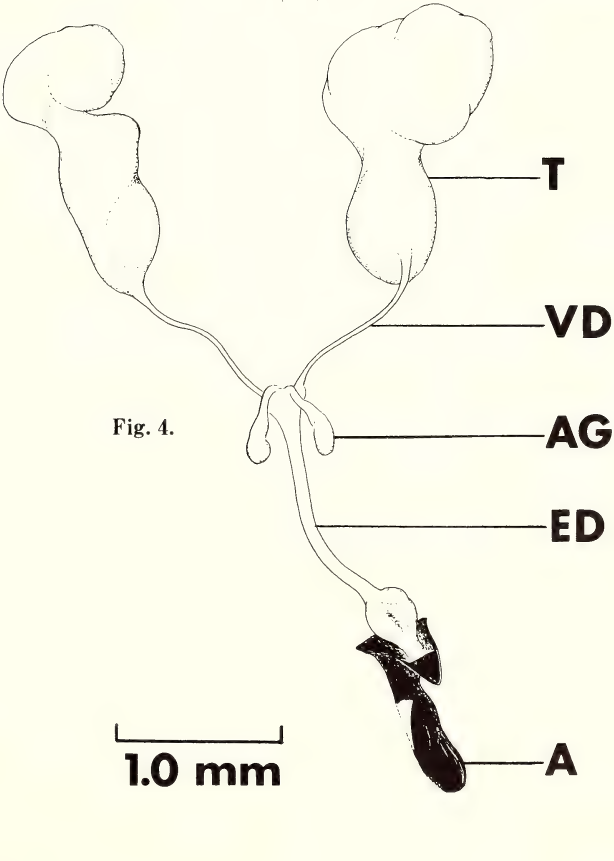


Fig. 4.

Fig. 3. Female reproductive organs. O, ovary; AG, accessory gland; S, spermatheca; GC, genital chamber

Fig. 4. Male reproductive organs. T, testis; VD, vas deferens; AG, accessory glands; ED, ejaculatory duct; A, aedeagus

tenebrosa specimens. Only one of five males had a crop, whereas all four females had small crops (Figure 1, Figure 2). Studies with *C. latifrons* present conflicting results: Catts (1963) reported a vestigal crop, whereas Singh and Judd (1966) described a crop proportional in size to that of other muscoid Diptera.

The ventriculus begins with a typical cardiac sac. This organ is termed the proventriculus by Lowne (1890), Hewitt (1914), Hori (1972), and the cardia by Singh and Judd (1966). The remainder of the *C. tenebrosa* ventriculus is tubular and of the same diameter throughout. This agrees with findings for *C. latifrons* by Catts (1963) and Singh and Judd (1966). Food remnants were found in the ventriculus and intestines of three male *C. tenebrosa* specimens. This must certainly be material held over from larval feeding since the flies had no opportunity to feed as adults. At the ventriculus-intestine junction, two Malpighian ducts are present. Each duct gives rise to two moniliform Malpighian tubules which extend among the organs of the abdomen. The rectum is similar in shape to that of other flies; four rectal pads are present on the anterior portion. Catts (1963) and Singh Judd (1966) reported similar observations for *C. latifrons.* Large tracheal air sacs extend from one-third to one-half of the length of the abdomen of *C. tenebrosa.* Townsend (1935) made no mention of air sacs in his studies of *Cuterebra* specimens.

Reproductive Tract

Figures 3 and 4 illustrate the internal reproductive system of female and male *C. tenebrosa,* respectively. They are similar to descriptions of other *Cuterebra* provided by Townsend (1935) and Catts (1963), although *C. tenebrosa* females have spherical spermathecae in contrast to the sausage-shaped spermathecae of *C. latifrons.*

According to Hori (1972), the majority of calypterate muscoid flies have three spermathecae, although several genera within Stomoxydinae (Muscidae) have but two. In the lower flies, the number of spermathecae ranges from zero to four. *C. tenebrosa* specimens have spermathecae arranged one on the upper left side of the genital chamber, one on top, and one on the upper right side of the chamber (1:1:1). In contrast, most other muscoid genera have two left and one right (2:1) or one left and two right (1:2) (Lowne 1890; Hewitt 1914; Hori 1972). A variety of spermathecal shapes were illustrated by Hori (1972) for muscoid flies; however, within genera the shapes were fairly consistent.

C. tenebrosa males are basically similar to other muscoid flies in the internal reproductive structures. One difference between *C. tenebrosa* and *C. latifrons* (Catts 1963) is that the accessory glands are smaller in relation to the testes in *C. tenebrosa.* This may be a function of the age of the fly, however, as Hori (1972) stated the shape of the testes of male muscoid flies correlated closely to the age.

CONCLUSIONS

The alimentary tract of *Cuterebra tenebrosa* is basically similar to other muscoid Diptera. The two main differences are the reduced or absent crop in males and the racemose salivary glands in *C. tenebrosa.*

In early *Cuterebra* literature, these bot flies were described as being without mouth parts. Although more recent work has shown the true nature of their mouth parts and alimentary system, no one has reported *Cuterebra* flies feeding or drinking. Apparently there is no food requirement for oviposition. In rearing several hundred *Cuterebra* flies in recent years, we have maintained them from eclosion to oviposition (usually five days) with no opportunity to feed. In most cases the resulting eggs have had a high fertility, although most females laid only 50-75% of their complement of eggs before dying.

ACKNOWLEDGEMENTS

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References

Baird, C. R. & C. L. Graham. 1973. **Cuterebra tenebrosa:** Description of immature stages and a redescription of the adult (Diptera: Cuterebridae) Can. Ent. 105:1281-1293.

Bennett, G. F. 1955. Studies on **Cuterebra emasculator** Fitch 1856 (Diptera: Cuterebridae) and a discussion of the status of the genus **Cephenemyia** Ltr. 1818. Can. J. Zool. 33:75-98.

Catts, E. P. 1963. The biology of **Cuterebra latifrons** Coquillett (Diptera: Cuterebridae). Ph.D. Dissertation, University of California, Berkeley. 174 pp. (unpub.)

Graham, C. L. & K. J. Capelle. 1970. Redescription of **Cuterebra polita** (Diptera: Cuterebridae) with notes on its taxonomy and biology. Ann. Entomol. Soc. Amer. 63:1569-1573.

Haas, G. E. & R. J. Dicke. 1958. On **Cuterebra horripilum** Clark (Diptera: Cuterebridae) parasitizing cottontail rabbits in Wisconsin. J. Parasitol. 44:527-540.

Hewitt, C. G. 1914. The House Fly, Cambridge University Press, London. 195 pp.

Hori, K. 1972. The works of the late Dr. Katshushige Hori. Comparative anatomy of the internal organs of the calypterate muscoid flies and the other works. Kanazawa, Japan. 306 pp.

Lowne, B. T. 1890. The anatomy, morphology, and development of the blowfly (**Calliphora erythrocephala**) I. Porter, London.

Singh, S. B. & W. W. Judd. 1966. A comparative study of the alimentary canal of adult calypterate Diptera. Proc. Entomol. Soc. Ont. 96:29-80.

Townsend, C. H. T. 1935. Manual of myiology, Part II Muscoid classification and habits. Townsend Pub., Sao Paulo, Brazil.

EURRHYPARA HORTULATA L. (*URTICATA* L.) ON THE PACIFIC COAST (LEPIDOPTERA: PYRALIDAE)

This attractive little moth, which can hardly be confused with anything else in the North American fauna, is native to Europe and temperate east Asia. It ranges from Ireland to the Amur-Ussuri region and Manchuria. It was established in Nova Scotia by 1907 at MacNab's Island and Truro. At present it has a wide range in the Northeast, extending from Newfoundland to Ontario and southward. The moth flies mainly in July, at night, is attracted to light and in the daytime is easily flushed. The main food-plant in Europe is nettle, *Urtica dioica* L., and other plants such as *Marrubium vulgare* L., *Stachys* sp., *Mentha* sp., *Calystegia sepium* Br. and *Ribes* sp. Probably it has other plant hosts also. Little is known about its food plants in North America.

Until now there were no records of *E. hortulata* having been collected on the Pacific coast. There are no specimens from this area in local collections or in the Canadian National Collection at Ottawa.

On 18 June, 1977 a perfect female specimen was seen resting on the ceiling of a living room in East Vancouver. It was in such immaculate condition that it was obvious that it was freshly emerged. Unfortunately, in my excitement, the specimen was somewhat damaged during capture. Four days later, another perfect specimen, a male, was flushed in the garden and collected. Another was observed in the garden on 23, 26 and 27 June but no further specimens were collected in order to give the species a chance to survive and become established in Vancouver. How the moth arrived in Vancouvr will remain a mystery. Most likely the first specimens were introduced last year, deposited eggs and produced moths this year. The host-plant here remains unknown. There are no nettles growing in the vicinity and the nearest place known to me where nettles grow in Vancouver is near the seawall in Stanley Park. There are other possible plant hosts, however, cultivated in our garden, such as *Stachys recta*, at least three different species of *Mentha*, *Calystegia sepium* and *Ribes* sp. The moth may have selected one of those plants on which to lay eggs.

In Europe the larva rolls the leaves or spins them together. The cocoon is spun in a sheltered place, usually under the bark, in autumn. Hibernation takes place as a prepupal larva which pupates in the spring. There is one generation per year. Next June or July should show whether the moth will establish itself in Vancouver or not. Unlike horticulturists and the Plant Protection Division, I hope it will.

References

Beirne, B.P. 1952. British Pyralid and Plume moths. London & New York.

Forbes, W. T. M. 1923. Lepidoptera of New York and neighbouring States. Part I, Ithaca.

Meyrick, E. 1968. A Revised Handbook of British Lepidoptera.

Munroe, E. 1976. **Pyralidae. Pyraustinae. Pyraustini.** The Moths of America North of Mexico. fasc. 13.2A.

W. Lazorko

EFFECT OF ANTI-AGGREGATIVE PHEROMONES 3,2-MCH AND *TRANS*-VERBENOL ON *DENDROCTONUS RUFIPENNIS* ATTACKS ON SPRUCE STUMPS

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ABSTRACT

Anti-aggregative pheromones 3,2-MCH and 3,2-MCH with *trans*-verbenol were released from open vials enclosed in perforated cans attached to both sides of 50 winter-cut spruce stumps which normally attract spruce beetles (*Dendroctonus rufipennis*). Although significantly fewer attacks occurred on treated than on untreated stumps, the attack density was not sufficiently reduced to be of practical value in controlling spruce beetle reproduction in this host material. There was no significant difference in reduction of beetle attacks between the 3,2-MCH and the 3,2-MCH with *trans*-verbenol treatments.

RESUME

On a libère à partir de fioles ouvertes placées à l'intérieur de canettes perforées, attachées aux "deux côtés" de 50 souches d'Epinette coupees en hiver, des phérormones anti-agglomérantes 3, 2-MCH et 3, 2-MCH avec *trans*-verbenol et qui normalement, attirent de Dendroctone de l'Epinette (*Dendroctonus rufipenns*). Malgré un nombre significativement réduit d'attaques contres les souches traitees, comparativement aux autres souches, la densité de l'infestation ne fut pas suffisamment diminuèe pour constituter un moyen pratique d'enrayer la reproduction du Dendroctone de l'Epinette dans cet arbre hôte. Il n'y eut pas de différence significative dans la baisse des attaques du Dendroctone entre les traitements 3, 2-MCH et 3, 2-MCH avec *trans*-verbenol.

INTRODUCTION

The spruce beetle, *Dendroctonus rufipennis* (Kirby), occurs throughout the range of spruce in Canada and the United States (Wood, 1963). At epidemic levels, it attacks and kills large volumes of mature standing spruce (*Picea engelmannii* Parry, *P. glauca* (Moench) Voss), and at endemic levels, it breeds principally in fresh spruce windfall, stumps and slash.

3,2-MCH ([3]-methyl-2-cyclohexen-1-one), an anti-aggregative pheromone produced by the Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopk., has been shown to mask the effect of the aggregative pheromones of this beetle (Rudinsky *et al.*, 1972). Other experiments with this pheromone applied to spruce logs have shown a similar anti-aggregative effect to spruce beetles (Rudinsky *et al.*, 1974; Kline *et al.*, 1974). A second pheromone, *trans*-verbenol (trans- 4, 6, 6-trimethylbicyclo - (3-1-1) -3-hepten-2-ol), is the principal aggregative pheromone of the mountain pine beetle, *Dendroctonus ponderosae* Hopk. (Pitman and Vité, 1969), but is an anti-aggregative pheromone component of the western pine beetle, *Dendroctonus brevicomis* Lec. (Wood, 1972). Results of experiments on the effect of *trans*-verbenol on Douglas-fir beetle are unclear; comparable experiments have given both aggregative and anti-aggregative results (Rudinsky *et al.*, 1972). Furniss *et al.* (1976) stated that *trans*-verbenol repressed attraction of spruce bettle to logs with and without the synthetic attractants frontalin and seudenol, but that its effect was less than that of 3, 2-MCH.

An experiment to determine the anti-aggregative effect of 3,2-MCH and 3,2-MCH with *trans*-verbenol on spruce beetle was carried out during the spring and summer of 1975, using attractive spruce stumps in a winter clearcut area in central British Columbia.

METHODS

Twenty 5-stump groups, in 10 pairs with approximately 50 m between groups in each pair, were selected throughout a large clear-cut area and treated as follows: 10 groups, one of each pair, were designated as controls and left untreated; the other 10 groups were alternately treated with 3, 2-MCH alone or with 3, 2-MCH and *trans*-verbenol. Closed perforated film cans, each containing an open 0.5 dr vial with 0.1 ml 3, 2-MCH (Rudinsky *et al.*,

1972), were placed on the centers of the north and south sides of each treated stump. For each stump treated with both 3, 2-MCH and *trans*-verbenol, a second open 0.5 dr. vial containing 0.15 ml of *trans*-verbenol was put in each can with the 3, 2-MCH. Vials were checked for evaporation throughout the flight period to ensure the presence of the two chemicals.

Stumps were treated by May 29 and left throughout June, the beetle flight period. After flight, six 10.16-cm-diameter bark samples were cut randomly from the north lower side of each stump. The number of entrance holes was counted on each sample and totalled for all samples in all stumps of each group. A randomization test for matched pairs (Siegel, 1956) was used to compare the 3,2-MCH-treated stumps to their respective controls, and 3,2-MCH + *trans*-verbenol treated stumps to their respective controls. Differences between treated and control pairs were calculated for each of the 3,2-MCH and 3,2-MCH - *trans*-verbenol groups, and the two treatments were compared to each other, using a randomization test for two independent samples (Siegel, 1956).

RESULTS AND DISCUSSION

The emission of 3,2-MCH alone and that of 3,2-MCH and/*trans*-verbenol at attractive spruce stumps resulted in a reduction in the number of beetle attacks compared to attacks on untreated stumps, although only two of the 10 treated replicates were not attacked (Table 1). The addition of *trans*-verbenol to 3, 2-MCH made no significant difference to the degree of reduction in the number of attacks.

The emission of 3, 2-MCH at spruce stumps produced a 50% reduction in attack density, with a spacing of less than 1 m between 3, 2-MCH containers on individual stumps. Rudinsky *et al.* (1974) used a 1.8 m spacing between 3, 2-MCH containers on downed spruce trees and achieved complete protection from attacks. Since the north aspects of the spruce stump bases are the most productive areas for spruce beetle brood in logging slash (Dyer and Taylor, 1971), the reduced attack density on 3, 2-MCH-treated stumps is not low enough to ensure population reduction in the next generation. The lower density broods would reduce competition and thereby possibly increase survival to maturity under suitable

TABLE 1. Spruce beetle attacks/m² from 600 samples on north sides of 100 stumps with two treatments and paired controls.

	3, 2-MCH		3,2-MCH + *trans* verbenol	
	TREATMENT	CONTROL	TREATMENT	CONTROL
Mean	12.3[1]	24.6	8.2[2]	16.5
Range	0 - 28.8	8.2 - 37.0	0 - 24.7	4.1 - 28.8

[1]differs from paired control @ 0.125 level of significance.
[2]differs from paired control @ 0.05 level of significance. No difference between MCH and MCH + *trans*-verbenol @ 0.05 level of significance.

environmental conditions. The difference between the reduction of attack on spruce stumps and that on downed trees may be due to the difference in environmental exposure around the treated material. Open logging slash, with greater air movement and higher temperatures, would tend to disperse the 3, 2-MCH faster than in a more sheltered stand environment, thereby producing a lower concentration of 3, 2-MCH at the source.

Therefore, 3,2-MCH apparently cannot be applied by this method as a practical means of reducing spruce beetle populations breeding in suitable logging slash.

References

Dyer, E. D. A. and D. W. Taylor. 1971. Spruce beetle brood production in logging slash and windthrown trees in British Columbia. Information Rept. BC-X-62. Can. Dept. Env., Pac. For. Res. Centre, Victoria, B.C.

Furniss, M. M., B. H. Baker and B. C. Hostetler. 1976. Aggregation of spruce beetles (Coleoptera) to seudenol and repression of attraction by methylcyclohexenone in Alaska. Can. Ent. 108: 1297-1302.

Kline, L. N., R. F. Schmitz, J. A. Rudinsky and M. M. Furniss. 1974. Repression of spruce beetle (Coleoptera) attraction by methylcyclohexenone in Idaho. Can. Ent. 106: 485-491.

Pitman, G. B. and J. P. Vité. 1969. Aggregation behavior of **Dendroctonus ponderosae** (Coleoptera: Scolytidae) in response to chemical messengers. Can. Ent. 101: 143-149.

Rudinsky, J. A., M. M. Furniss, L. N. Kline and R. F. Schmitz. 1972. Attraction and repression of **Dendroctonus pseudotsugae** (Coleoptera: Scolytidae) by three synthetic pheromones in traps in Oregon and Idaho. Can. Ent. 104: 815-822.

Rudinsky, J. A., C. Sartwell, Jr., T. M. Graves and M. E. Morgan. 1974. Granular formulation of methylcyclohexenone: an antiaggregative pheromone of the Douglas-fir and spruce bark beetles (Col., Scolytidae). Z. ang. Ent. 75: 254-263.

Siegel, S. 1956. Non parametric statistics. McGraw-Hill Book Co. Inc., New York. 312 pp.

Wood, D. L. 1972. Selection and colonization of ponderosa pine by bark beetles. In: Insect/Plant Relationships; ed: H. F. van Emden. Symp. Roy. Entomol. Soc. (London) 6, 101-117.

Wood, S. L. 1963. A revision of the bark beetle genus *Dendroctonus* Erichson (Coleoptera: Scolytidae). Gt. Basin Nat. 23: 117 pp.

INSECTS COLLECTED FROM AN ALPINE-SUBALPINE REGION IN SE BRITISH COLUMBIA

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ABSTRACT

Insects were caught in a subalpine area of southeastern British Columbia. The list consists of 23 spp. and 37 genera, in families of five orders. The insects were collected during July and August, 1975 as part of a larger study of the ecology of mountain caribou in the Poplar Creek area, north of Nelson, B.C.

INTRODUCTION

There are few identified collections of insects in the alpine-subalpine environment of British Columbia. This is a report on insects collected in the central Selkirk Mountains of British Columbia during July and August 1975. The paper by Allan (1969) is most similar to the present report, although his collections were mainly from lower elevations and limited to the family Syrphidae. Other related studies, but not from British Columbia, include those of Chapman (1954), Dodge and Seago (1954) and Mani (1955).

The insects reported here were obtained during a survey for potential pests of mountain caribou (*Rangifer tarandus montanus*) inhabiting the alpine-subalpine environment at the same time of the year. The caribou is the subject of a study by Harling and Snyder (unpublished).

METHODS AND STUDY AREA

The insects were sampled between 10 July and 27 August, 1975 with pieces of wire screen (40x50 cm), smeared with grease and placed on supports about 0.9 m above ground level. Additional collections were made with hand nets and a Malaise trap. The insects were first identified in the laboratory and the identifications verified by the Biosystematics Research Institute, Canada Department of Agriculture, Ottawa, Ontario.

General meteorological data were obtained from maximum and minimum thermometers, a sling psychrometer, and a simple rain gauge; wind speed and direction were estimated at the time when samples were collected from the traps.

The collection was mainly from the extreme north fork at the west end of the headwaters of Poplar Creek (50° 21′ N, 117° 21′ W) in southeastern British Columbia. The area comprised alpine meadows, talus slopes, receding snow patches and the upper fringe of climax stands of englemann spruce (*Picea englemanni*) and subalpine fir (*Abies lasiocarpa*). The collections were made between 1500 and 1650 m elevation.

RESULTS

Table I lists the insects collected during the study. Only those taxa verified by the Biosystematics Research Institute have been included. Dipterans alone made up about 78% of the catch. The families Bibionidae, Syrphidae, Tabanidae and Tipulidae comprised more than 50% of all the Dipterans caught. Hemip-

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Table 1. Insects collected from the Poplar Creek area of SE British Columbia, July and August, 1975.

COLEOPTERA		
	Buprestidae	**Agrilus sp.**
		Melanophila drummondi (Kby.)
	Cantharidae	**Podabrus scaber** (LeC.)
	Carabidae	**Phloeopterus sp.**
	Cerambycidae	**Anoplodera aspera** (LeC.)
		Xylotrechus longitarsis (Csy.)
	Chrysomelidae	**Chryomela sp.**
		Syneta subalpina (Edwards)
	Coccinellidae	
	Elateridae	**Ctenicera hoppingi** (Van Dyke)
		Ctenicera sylvatica (Van Dyke)
	Lycidae	**Dictyopterus sp.**
	Scarabeidae	**Aphodius sp.**
	Scolytidae	**Orthotomicus sp.**
		Trypodendron lineatum (Oliv.)
	Cryphalini	
	Scraptiidae	**Anaspis sp.**
	Staphylinidae	**Ptomaphagus sp.**
	Omaliinae	
DIPTERA		
	Anthomyiidae	**Hylemya sp.**
		Hylemya (Pegohylemia) fugax (Meigen)
		Hylemya (Botanophila) spinidens (Malloch)
	Bibionidae	**Bibio sp.**
	Calliphoridae	**Phormia regina** (Mg.)
	Drosophilidae	**Clastopteromyia inversa** (Walker)
	Empididae	**Drapteris sp.**
		Empis brachysoma (Coquillett)
	Tachydrominae	
	Muscidae	**Lasiops medius** (Stein) ♂
	Rhagionidae	**Symphoromyia atripes** (Bigot)
	Syrphidae	**Chrysotoxum sp.** ♂
		Melangyna sp. ♂
		Syrphus torvus (O.S.) ♂
	Tabanidae	**Hybomitra osburni** (Hine)
	Tachinidae	**Nowickia pilosa**
	Tipulidae	
	Limoniinae	
	Tipulinae	
HEMIPTERA		
	Miridae	**Irbisia nigripes** (Kgnt)
		Lygus varius (Kgnt)
HYMENOPTERA		
	Bombidae	**Pyrobombus (Pryrobambus) flavifrons flavifrons** (Cresson)
	Colletidae	**Hylaeus sp.**
	Siricidae	**Urocerus gigas flavicornis** (F.)
	Tenthredinidae	**Tenthredo sp.**
		Dolerus (Dolerus) sp.
	Pamphiliidae	**Pamphilius sp.**
LEPIDOPTERA		
	Nymphalidae	**Boloria epithore** (Edwards)

terans and Lepidopterans each comprised less than 2% of the total; Coleopterans and Hymenopterans represented the rest.

The temperature during the study ranged from 3.4°C to 23.9°C with humidity from 43-88%. The maximum precipitation recorded on a sampling day was 0.48 cm and on other days was often zero. Wind speed varied from force 0 to force 2 and was usually from the south.

Catches were largest during periods of high temperature, low precipitation, and low humidity. No clear trend was noted with reference to wind speed or direction. Other authors (Chapman, 1954; Mani, 1962) have confirmed that the meteorological factors recorded here do have a marked effect on insect activity at high elevations.

DISCUSSION

At least an additional 25 species were caught but were not identified by the Biosystematics Research Institute because they were damaged in transit.

The methods employed in this investigation were relatively simple, so that the analysis of relative abundance could not be sophisticated. However, the predominance of Dipterans in relation to other groups was significant and consistent with other surveys of alpine insect fauna (Chapman, 1954; Dodge and Seago, 1954; Mani, 1955, 1962). Among families, the Syrphidae and Tabanidae were abundant as also reported by Chapman (1954) but the Tachinidae which he found to be abundant were represented here by a single specimen.

A number of the Dipteran species listed in Table I may be associated with the caribou population of the area. In particular, the blowfly *(Phormia regina* (Mg.)) and the tabanid *(Hybomitra osburni* (Hine)) could be potential caribou pests because related genera have been confirmed as large mammal pests (Prior, 1968). Bot and warble flies parasitize caribou (Bergerud, 1961; Low, 1964; Layser, 1974) and although no such species were recorded in our samples, a close relative (the tachinid *Nowickia pilosa*) was caught. The mountain caribou continue to be studied in the area and it is hoped that some confirmation of their insect pests will be forthcoming.

ACKNOWLEDGEMENTS

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References

Allan, D. A. 1969. Syrphidae collected mostly in southern areas of the Okanagan Valley, British Columbia. J. Entomol. Soc. Brit. Columbia 66: 19-21.

Bergerud, A. T. 1961. The reproductive season of Newfoundland caribou. (Unpublished) 31 pp.

Chapman, J. A. 1954. Studies on summit frequenting insects in western Montana. Ecology 35: 41-49.

Dodge, H. R. and J. M. Seago. 1954. Sarcophagidae and other Diptera taken by trap and net on Georgia mountain summits in 1952. Ecology 35: 50-59.

Layser, E. F. 1974. A review of the mountain caribou of northeastern Washington and adjacent northern Idaho. J. Idaho Acad. of Science, Special Res. Issue. No. 3. 63 pp.

Low, W. A. 1964. A general ecological study of mountain caribou in Tweedsmuir Provincial Park (Unpublished report of work supported by the University of British Columbia and the B.C. Fish and Wildlife Branch). 4 pp.

Mani, M. S. 1955. Entomological survey of the Himalaya, Pt. IV - Expedition to the Upper Chenab Valley, 1954. Agra Univ. J. Res. (Sci.) 4: 157-170.

Mani, M. S. 1962. Introduction to high altitude entomology. Methuen, London. 302 pp.

Prior, R. 1968. The Roe Deer of Cranbourne Chase. Oxford University Press. 222 pp.

OVERWINTERING SURVIVAL OF *PISSODES STROBI* (PECK) (COLEOPTERA: CURCULIONIDAE) IN SITKA SPRUCE LEADERS[1]

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Across most of its range, *Pissodes strobi* Peck[3] overwinters as an adult in the duff at the base of brood hosts from which it emerged in autumn (Belyea and Sullivan 1956; Stevenson 1967). On the west coast of British Columbia, mild winters apparently permit adult *P. strobi* to overwinter on the bole and laterals of Sitka spruce (Gara, Carlson, and Hrutfiord 1971; McMullen and Condrashoff 1973). Silver (1968) suggested that although some *P. strobi* in coastal B.C. overwinter as larvae in host leaders, they may be unable to complete their development the following spring.

On June 8, 1976, I collected 26 Sitka spruce leaders attacked in 1975 from two plantations near Port Renfrew, Vancouver Island. These terminals were maintained in the laboratory at approximately 20°C. Sixteen adult *P. strobi* (9 ♂♂ and 7 ♀♀) emerged during a 2-week period in late June. Five additional male weevils emerged in late July, from Sitka spruce leaders collected at the same sites on July 7, 1976.

After a count of weevil emergence holes chewed through the intact outer bark, the leaders from the June 8, 1976 collection were dissected. A total of 737 chip cocoons in the xylem and pith contained 36 dead adults (4.9%) that had failed to emerge. An additional 75.3% had apparently died in chip cocoons prior to completing pupation. The count of weathered emergence holes indicated that 130 adults (17.6%) had emerged in late summer to fall, 1975. The 16 *P. strobi* that emerged in early summer, 1976 constituted 2.2% of the total chip cocoon population or 11.0% of the total emergent population.

These results indicate that *P. strobi* can successfully overwinter in the larval stage in Sitka spruce leaders in coastal B.C.

Acknowledgements

I thank W. Coombs for allowing me to collect weevils on plantations managed by B.C. Forest Products Ltd., N. Yalpani for assistance with field work, and Dr. J. H. Borden for review of the manuscript.

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[2]Graduate student.

[3]Smith and Sugden (1969) designated the former Sitka spruce weevil, *Pissodes sitchensis* Hopkins and the Engelmann spruce weevil, *P. engelmanni* Hopkins, as ecotypes of *P. strobi* Peck on the basis of morphological and cytogenetic similarities (Manna and Smith 1959; Smith 1962).

References

Belyea, R. M. and C. R. Sullivan. 1956. The white pine weevil; a review of current knowledge. For. Chron. 32: 58-67.

Gara, R. I., R. L. Carlson, and B. F. Hrutfiord. 1971. Influence of some physical and host factors on the behaviour of the Sitka spruce weevil, *Pissodes sitchensis*, in southwestern Washington. Ann. Ent. Soc. Am. 64: 467-471.

Manna, G. K. and S. G. Smith. 1959. Chromosomal polymorphism and inter-relationships among bark beetles of the genus *Pissodes* Germar. The Nucleus 2: 179-208.

McMullen, L. H. and S. F. Condrashoff. 1973. Notes on dispersal, longevity, and overwintering of adult *Pissodes strobi* (Peck) (Coleoptera: Curculionidae) on Vancouver Island. J. Ent. Soc. B.C. 70: 22-26.

Silver, G. T. 1968. Studies on the Sitka spruce weevil, *Pissodes sitchensis*, in British Columbia. Can. Ent. 100: 93-110.

Smith, S. G. 1962. Cytogenetic pathways in beetle speciation. Can. Ent. 94: 941-955.

Smith, S. G. and B. A. Sugden. 1969. Host trees and breeding sites of native North American *Pissodes* bark weevils, with a note on synonymy. Ann. Ent. Soc. Am. 62: 146-148.

Stevenson, R. E. 1967. Notes on the biology of the Engelmann spruce weevil, *Pissodes engelmanni* (Curculionidae: Coleoptera) and its parasites and predators. Can. Ent. 99: 201-213.

A NEW *CLASTOPTERA* FROM SAGEBRUSH (RHYNCHOTA: HOMOPTERA: CERCOPIDAE)

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ABSTRACT **J. Ent. Soc. B.C.**

Clastoptera atrapicata n. sp. (Homoptera: Cercopidae) is described from sagebrush *(Artemisia tridentata* Nutt) in central British Columbia and Oregon. This species is closely allied to *C. brunnea* Ball, and, like it, exhibits considerable variation in colour pattern of the face. The ovipositor and colour varieties are illustrated and compared with those of its related species.

The genus *Clastoptera* in America north of Mexico was revised by Doering (1928) to include 29 species. Of these, six were distinctive in having fewer pronotal striae (10 or fewer on midline) than the other species, and in having arid-adapted hosts: sagebrush *(Artemisia tridentata* Nutt) and rabbit brush *(Chrysothamnus* spp.). Two of these six, *sierra* Doering and *binotata* Ball, are wholly black in both sexes; one, *delicata* Uhler, is yellow with black pronotal bars in both sexes; and in the remaining three, the males are black and the females are yellow with black pronotal bars. To the latter group I now add a fourth previously unrecognized species.

Clastoptera atrapicata n. sp.
(Figs. 7-10, 12, 16, 17)

Body form as in other *Clastoptera*, but with frons considerably inflated, tylus longer than median length of vertex in both sexes, in dorsal aspect with tylus appearing about as long as median length of vertex (Fig. 12). Length: male, 2.9-3.5 mm; female, 3.2-4.2 mm.

Male. Colour blackish-brown except for pale areas on tegmina around bullae, yellow spot at centre of costa, and yellow spots on lora; similar to *C. brunnea* Ball in colour. Male genitalia as in *brunnea* (Doering 1928, pl. XXV, fig. 3).

Female. Colour pale yellow, overlaid with two heavy black bars across fore margin of pronotum and between eyes, and finer brown lines (6-9 in number) across pronotum; face variously marked with fuscous and black (Figs. 7-10); tegmina mottled with fuscous, paler on apical cells and along edge of transverse creases; legs pale, banded with fuscous; similar to *brunnea* in colour.

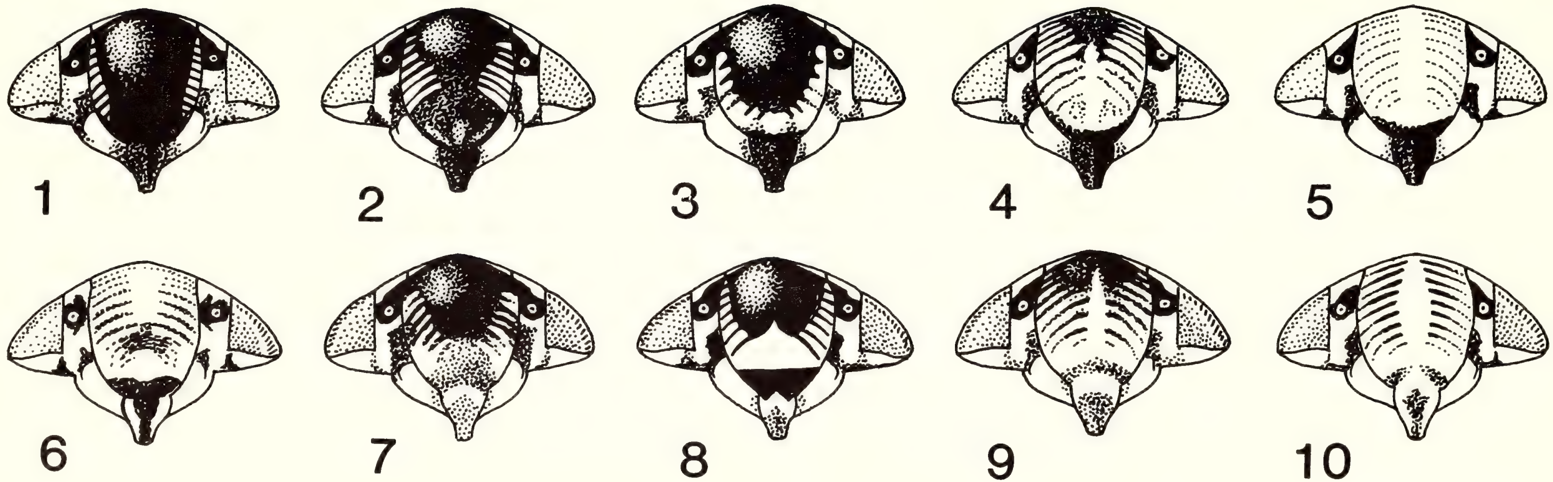
Inner rami of ovipositor parallel-margined on basal half, strongly tapered apically, ventral margin curved dorsad, dorsal margin straight, armed with two close-set teeth near midlength (Figs. 16, 17); similar to ovipositor of *C. lugubris* Ball.

Types. Holotype ♀, Seton L., Lillooet, B.C., 30 June 1926 (J. McDunnough) on sagebrush. Paratypes: 14♂♂, 6♀♀, same data as holotype; 5♂♂, 13♀♀, 17 mi SE Spences Bridge, B.C., 8 Aug. 1976 (K. G. A. Hamilton) on sagebrush; 1♂, SE slope Glass Butte, 12 mi E Hampton, Lake Co., Ore., 12 July 1968 (J. D. Lattin) 68-27; 1♀, 14 mi N Burns, Harney Co., Ore., 14 Aug. 1971 (P. W. Oman). Holotype and 38 paratypes no. 14073 in the Canadian National Collection, Ottawa; 2 paratypes in the collection of Oregon State University, Corvallis.

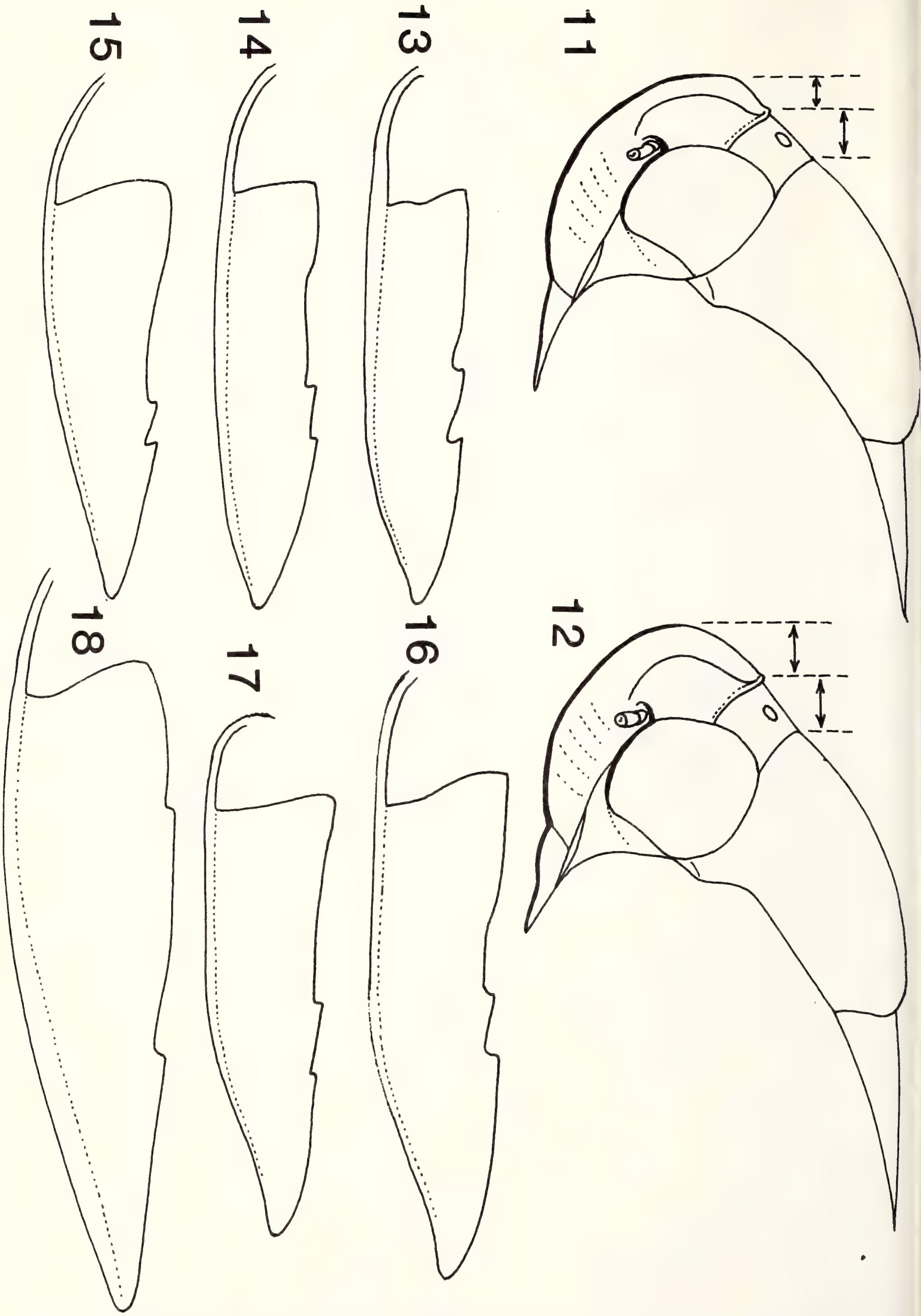
Remarks. C. atrapicata is closely allied to *brunnea* Ball, *lugubris* Ball and *lineatocollis* Stål. Males of *atrapicata* may be distinguished from all three by the more strongly inflated frons and longer tylus (Fig. 12). In dorsal aspect the tylus appears to be as long as the vertex, while in the three allied species the tylus appears half as long (Fig. 11). Males of *lugubris* and *lineatocollis* also have more extensive pale markings on the face (Doering 1928, pl. IV, fig. 2a).

Females of *lugubris* differ from those of *atrapicata, brunnea* and *lineatocollis* in their larger size (3.6-4.6), in having the tylus very strongly produced, in dorsal aspect longer than the vertex, and in having the pronotal bars of equal width and darkness with the interocular bar.

Females of *atrapicata* can be distinguished from those of all its other relatives by the shape of the apex of the inner rami of the ovipositor, and by the placement of the ovipositor teeth near the centre of the blade (Figs. 16, 17). The facial markings of *atrapicata* are also distinct: the base of the clypellus always has a pale transverse band (Figs. 7-10) not found in *brunnea* and *lineatocollis* (Figs. 1-6); furthermore, the majority of specimens have the upper half of the frons black (Figs. 7-8), a condition not found in related species. The variability of the facial markings show the close relationship between *brunnea* and *atrapicata.*



Figs. 1-10. Facial patterns in **Clasptoptera** species. 1-5, C. **brunnea** Ball; 6, C. **lineatocollis** Stål; 7-10, C. **atrapicata** n. sp.



Figs. 11-12. Profile of head and pronotum of **Clastoptera** species with apparent extent of frons and vertex from dorsal aspect indicated by arrows. 11, C. **brunnea**; 12, C. **atrapicata**.

Figs. 13-18. Ovipositor blades of **Clastoptera** species, lateral aspect. 13, 14, C. **brunnea**; 15, C. **lineatocollis**; 16, 17, C. **atrapicata**; 18, C. **delicata** Uhler.

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I wish to thank Dr. P. W. Oman of Oregon State University, Corvallis for loan of specimens of *Clastoptera* for comparison with those deposited in the Canadian National Collection.

Reference

Doering, K. C. 1928. The genus Clastoptera in America North of Mexico. Kans. Univ. Sci. Bull. 18 (1): 5-153.

PTEROSTICHUS STRENUUS PANZ, A NEWLY-DISCOVERED PALAEARCTIC SPECIES IN THE VANCOUVER AREA (COLEOPTERA: CARABIDAE)

There are about 17 species of palaearctic Carabids known to be introduced from Europe into British Columbia, largely to the Vancouver area. Most were known for some time but some were discovered only recently. Lindroth (1957), in his excellent treatise on faunal connections between Europe and North America, postulated that practially all of those species were introduced with ship's ballast (Scudder 1958). An attempt is being made by the Entomological Society of Canada in its Biological Survey Project to collect all the available data on the distribution of introduced *Carabidae* in this province. I hope to compile a detailed list of the species with their known places of occurrence in the near future. Thus, this note may be of interest.

To the list of introduced species compiled from Lindroth's monograph (1963-1969) and supplemented by my own collecting and observation during the past 29 years I am able to add *Pterostichus strenuus* Panz., which has been taken recently in Vancouver.

The first specimen, a female, was collected on 8 June, 1968 on the marshy edge of a ditch, close to Beaconsfield Park in East Vancouver. All attempts to collect more specimens at the time were unsuccessful. Three more specimens, a male and two females, were collected by Prof. G. G. E. Scudder of UBC on 21 August, 1973 in a marshy area at the foot of Olympic Street in Vancouver (UBC Coll.). These specimens are at present the only records from the Pacific Coast of North America.

Pterostichus strenuus is distributed through the whole northern Palaearctic. In North America it has been known since 1937, restricted to a small area of southeastern Newfoundland, where it is a species of open, moderately moist grassland, often close to the sea (Lindroth, 1955). In Vancouver it appears to be more hygrophilous and less common.

References

Lindroth, G. H. 1955. The Carabid beetles of Newfoundland. Lund.

Lindroth, C. H. 1957. The faunal Connections between Europe and North America. New-York-Stockholm.

Lindroth, C. H. 1963-1969. The ground-beetles (Carabidae, excl. Cicindelinae) of Canada and Alaska. Lund.

Scudder, G. G. E. 1958. A new aspect on the faunal connections between Europe and the Pacific Northwest. Proc. Ent. Soc. of B.C. Vol. 55 p. 36.

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FURROW APPLICATION OF INSECTICIDE AS A METHOD OF CONTROLLING WIREWORMS IN POTATO LAND

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ABSTRACT

Three methods of applying insecticides for the control of the wireworm, *Agriotes obscurus* L., were tested using fonofos and terbufos. Most treatments gave significantly more marketable tubers than the control. The furrow treatment gave more consistent results than broadcast or side-dress and, at 1.1 or 2.2 kg a.i./ha, gave control equal to, or better than, the broadcast treatment at 5.6 kg a.i./ha. Analyses by gas chromatography using a flame photometric detector for residues in potatoes grown in treated soil showed residues to be less than 0.02 ppm.

INTRODUCTION

Fonofos is one of the most widely and used insecticides for wireworm control in potatoes. It is usually applied as granules, broadcast at 5 to 6 kg a.i./ha and mixed into the soil by discing and rototilling before planting. Broadcast treatments are expensive because of the extra cultivation to apply and mix the insecticide into the soil, and the expense increases with increasing rates of application. This high cost is acceptable only if control is good. Efficacy varies, however, even at a high rate of application, especially in heavy infestations of wireworms (Wilkinson *et al.* 1977). Costs are lower with either side-dressings or furrow treatments because the insecticide can be applied at planting time. Side-dress has been tested more often than furrow treatments.

The effectiveness of side-dress treatments also varies. Onsager *et al.* (1975) found side-dressings of fonofos nearly as effective as broadcast treatments. Carpenter and Scott (1974) found no significant difference between fonofos broadcast at 4.5 kg a.i./ha and post-planting side-dress at 7.8 kg a.i./ha to control the wireworm *Limonius californicus* (Mann.). in 3 experiments, Scott and Carpenter (1976) testing methods of application to control *L. californicus* found no significant difference between fonofos broadcast at 4.5 kg a.i./ha and side-dressed at 7.1 kg a.i./ha. In one of these tests there was no significant difference between side-dress treatments at 7.1 and 2.7 kg a.i./ha. Toba *et al.* (1976) found that both terbufos and fonofos, side-dressed at about 2.2 kg a.i./ha, gave significantly better control of a light infestation of *L. californicus* than when broadcast at 4.0 kg a.i./ha. However, Toba *et al.* (1977) found that a broadcast treatment at 6.7 kg a.i./ha gave significantly better control than a side-dress treatment at 2.2 kg a.i./ha.

The furrow treatment has not been tested extensively. Lilly (1973) found fonofos at 2.2 kg a.i./ha gave good control of *L. californicus* and was as effective as the broadcast treatment at 5.6 kg a.i./ha. Scott and Carpenter (1976) found the furrow method at 7.1 kg a.i./ha gave significantly better control than the broadcast treatment of 4.5 kg a.i./ha in one experiment but in another found no significant difference.

The two experiments reported here were designed primarily to test the furrow method of application to control wireworms and to compare it with the broadcast and side-dress methods.

MATERIALS AND METHODS

The experiments were conducted in silt infested with *A. obscurus* L. Fonofos and terbufos were tested by 3 methods of application at several rates (Tables 1, 2). Potatoes grown in 1976 at the site of the first experiment were severely damaged despite a broadcast treatment of fonofos at about 5.6 kg a.i./ha made by the farmer. Both fonofos and terbufos were tested at this site in 1977. The site of the 2nd experiment had been in sod for several years and here only fonofos was tested. The experimental plots were 8 x 2 m. In the broadcast treatment the insecticide was spread evenly over the soil surface then rototilled to a depth of 10 cm. Side-dressings were applied in furrows made on each side of the row and the insecticide was placed 7 cm from the centre, 2.5 cm below the level of the seed. In the furrow treatments, the insecticide was applied with the seed. Each treatment was replicated 4 times. Potatoes, cv. Netted Gem, were planted the same day the treatments were made.

At harvest, 50 tubers from each plot were examined for wireworm damage and the number of feeding holes in each tuber was recorded. Statistical significance of the data was deter-

TABLE 2. A comparison of 3 methods of applying fonofos to control *A. obscurus* in soil recently in sod, Cloverdale, B.C. 1977

Insecticide	Method of Application	Rate a.i. kg/ha	Marketable tubers %	Reduction of unmarketable tubers %
Fonofos 10 G	Broadcast	5.6	93.5 a[1]	80.9
Fonofos 10 G	Furrow	1.1	93.0 a	79.4
Fonofos 10 G	Furrow	2.2	92.0 a	76.5
Fonofos 10 G	Side-dress	2.2	87.0 a	61.8
Check	—	—	66.0 b	—

[1]Means followed by the same letter are not significantly different at the 5% level of probability.

mined by analysis of variance and Duncan's multiple range tests (Duncan 1955).

To detect residues of fonofos and fonofos oxygen analogue shredded potato was extracted first with acetone then with ethyl acetate. The solvent was evaporated leaving water which had been co-extracted from the potato. This was re-extracted with ethyl acetate. Following solvent reduction, clean-up was by column chromatography on a mixed bed of alumina, silica gel, Florisil and charcoal. Analysis was by gas chromatography using a flame photometric detector (P mode). To detect terbufos and its oxygen analogue sulfone, potato tissue was extracted by acetone followed by 2 extractions with ethyl acetate. Acetone was removed by partitioning into a large volume of water and the remaining ethyl acetate was concentrated to a suitable volume. A sample aliquot was cleaned up by column chromatography on Florisil, silica gel, alumina and charcoal. Analysis was by gas chromatography using a flame photometric detector (P mode). A more detailed description of these analytical procedures will be published later.

TABLE 3. Insecticide residues found in potatoes grown in soil treated by 3 methods of application

Method	Rate a.i. kg/ha	Fonofos 10 G		Terbufos 15 G	
		Fonofos PPM	Oxygen analogue PPM	Terbufos PPM	Oxygen analogue sulfone PPM
Experiment 1					
Furrow	1.1	.002[1]	ND[2]	T[3]	ND
Furrow	2.2	.017	ND	ND	ND
Broadcast	5.6	.004	ND	ND	ND
Side-dress	2.2	ND	ND	ND	ND
Check	—	ND	ND	ND	ND
Experiment 2					
Furrow	1.1	.001	ND		
Furrow	2.2	.004	ND		
Broadcast	5.6	.004	ND		
Side-dress	2.2	.002	ND		
Check	—	ND	ND		

[1]Values given are averages of two analyses
[2]ND=none detected
[3]T=trace

RESULTS AND DISCUSSION

In the first experiment (Table 1) all treatments except tuberfos granules side-dressed at 2.2 kg a.i./ha gave significantly more marketable tubers than the control. The furrow treatments gave the best control with no significant difference between fonofos and terbufos nor between the 1.1 and 2.2 kg a.i./ha rates. Terbufos broadcast at 5.6 kg a.i./ha was as effective as the furrow treatments but fonofos at 5.6 kg a.i./ha gave significantly fewer marketable tubers. Terbufos side-dressed at 2.2 kg a.i./ha was significantly more effective than fonofos side-dressed at the same rate.

In the second experiment (Table 2) only fonofos was tested. Again, all treatments were significantly better than the check, with no significant difference between treatments.

Our results show that the furrow, side-dress, or broadcast treatments were equally effective. The efficiency of the lower rates tested suggests that the rate of 7.1 kg a.i./ha, tested by Scott and Carpenter (1976), and possibly 2.24 kg a.i./ha tested by Lilly (1973), were unneces-

TABLE 1. Relative effectiveness of 2 insecticides applied by 3 methods for controlling *A. obscurus*, Cloverdale, B.C. 1977

Insecticide	Method of Application	Rate a.i. kg/ha	Marketable tubers %	Reduction of unmarketable tubers %
Terbufos 15 G	Furrow	2.2	93.0 a[1]	84.8
Fonofos 10 G	Furrow	1.1	90.0 ab	78.3
Fonofos 10 G	Furrow	2.2	89.5 ab	77.2
Terbufos 15 G	Furrow	1.1	89.5 ab	77.2
Terbufos 15 G	Broadcast	5.6	86.5 ab	70.6
Terbufos 15 G	Side-dress	2.2	79.5 bc	55.4
Fonofos 10 G	Broadcast	5.6	70.5 cd	35.9
Fonofos 10 G	Side-dress	2.2	60.5 de	14.1
Check	—	—	54.0 e	—

[1]Means followed by the same letter are not significantly different at the 5% level of probability.

sarily high. However, different soil types and different species of wireworms may require heavier rates and each should therefore be tested to determine the optimum rates. Onsager (1969) reported symptoms of phytotoxicity in foliage and a reduction in yield when potatoes were side-dressed with fonofos at 2.1 kg a.i./ha after the foliage appeared. We observed no phytotoxicity.

Lilly (1973), and Scott and Carpenter (1976) did not give residue data for fonofos granules. The results of our residue analyses (Table 3) show that even at 2.2 kg a.i./ha, fonofos residues were negligible in tubers harvested 128 days after treatment and the fonofos oxygen analogue was not detected. Results were similar with terbufos. Although furrow treatment at 2.2 kg a.i./ha gives a concentration of about 15 times greater than broadcast treatment at 5.6 a.i./ha fonofos, residues in tubers from furrow-treated plots were 0.02 ppm or less, only slightly more than from the other treatments. No residues were found in potatoes from the control plots in the field that had been broadcast-treated with fonofos in 1976. Most of the insecticides would break down in a year but any residue would be diluted further by ploughing to a depth of 20 cm.

Either insecticide at 1.1 kg a.i./ha in the furrow gave control equal to that of broadcast at 5.6 kg a.i./ha at about 20% of the cost. Furthermore, furrow treatment eliminates the extra expense of spreading and incorporating the insecticide in the soil.

REFERENCES

Carpenter, G. P., and D. R. Scott. 1974. Sugar beet wireworm control in potatoes in Idaho. J. Econ. Entomol. 65: 773-5.

Duncan, D. B. 1955. Multiple range and multiple F. tests. Biometrics 11: 1-42.

Lilly, C. E. 1973. Wireworms: efficacy of various insecticides for protection of potatoes in southern Alberta. J. Econ. Entomol. 66: 1205-7.

Onsager, J. A. 1969. Nonpersistent insecticides for control of Pacific Coast wireworm. Ibid. 62: 1065-7.

Onsager, J. A., B. J. Landis, and L. Fox. 1975. Efficacy of fonofos band treatments and a sampling plan for estimating wireworm populations on potatoes. Ibid. 68: 199-202.

Scott, D. R., and G. P. Carpenter. 1976. Placement of fonofos for wireworm control on potatoes in Idaho. Ibid. 69: 444-6.

Toba, H. H., B. J. Landis, and L. L. Foiles. 1976. Potato *L. californicus* control, Ellensburg, Washington 1972: (Veg. 83). Insecticide and Acaracide Tests 1: 66.

Toba, H. H., J. E. Turner, D. M. Powell, and W. T. Mander. 1977. Potato wireworm control, Pasco, Washington, 1975: (Veg. 82). Ibid 2: 67.

Wilkinson, A. T. S., D. G. Finlayson and C. J. Campbell. 1977. Soil incorporation of insecticides for control of wireworms in potato land in British Columbia. J. Econ. Entomol. 70: 755-8.

EFFICACY OF INSECTICIDES AGAINST GEOMETRID LARVAE, *OPEROPHTERA* SPP., ON SOUTHERN VANCOUVER ISLAND, BRITISH COLUMBIA[1]

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ABSTRACT

Permethrin, acephate, diazinon, malathion, endosulfan, methoxychlor, Imidan, naled and a spray containing surfactant only were the most effective treatments for control of winter moth, *Operophtera brumata* (L.), and Bruce spanworm, *O. bruceata* (Hulst), on apple in the tight cluster bud stage. Resmethrin, trichlorfon, and Dipel and Thuricide formulations of *Bacillus thuringiensis* were less effective. The growth disruptor, Dimilin, provided good control at the pink bud stage. At this same stage, sprays with surfactant only were no better than untreated controls.

INTRODUCTION

Outbreak populations of hardwood-defoliating geometrid larvae on southern Vancouver Island in 1976 were composed of about 10% Bruce spanworm, *Operophtera bruceata* (Hulst) and 90% winter moth, *O. brumata* (L.) (Gillespie *et al* 1978). Both species are very similar in appearance, habits and hosts. The Bruce spanworm is a North American species which occurs across southern Canada and the northern U.S.A. The winter moth is a European insect which became established in Nova Scotia (Cuming 1961). The Vancouver Island outbreak is the first record of winter moth from western North America.

Both moths feed on various ornamental, shade and fruit trees. DDT, lead arsenate and azinphosmethyl controlled winter moth in Nova Scotia (Sanford and Herbert 1966). Azinphosmethyl, diazinon and endosulfan controlled Bruce spanworm on apples in the Okanagan Valley, British Columbia (McMullen 1973). Dimilin, an insect growth disruptor, has also shown promise as a winter moth control (Pree 1976). This paper examines the efficacy of 13 insecticides for control of geometrids involved in the current outbreak on Vancouver Island. Examination of larval characteristics (Eidt and Embree 1968) indicate that these are mostly winter moth, with a small population of Bruce spanworm.

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CONTROL EXPERIMENTS

Treatments listed in Table 1 were applied to dwarf apple trees (variety unknown) in the tight cluster bud stage in a neglected orchard on the campus of the University of Victoria. Resmethrin was applied with a battery-operated Turbair ULV applicator. All other materials were applied to the point of run-off with a hand-operated Solo Sprayer Model 425. Surfactant Triton B 1956 was added to all sprays at 30 ml per 100 litres. The experimental plot consisted of 57 trees in randomized complete blocks containing 19 treatments per block. There were 3 single-tree replicates per treatment. Living larvae were counted on 10 leaf clusters selected at random from each tree 8 and 14 days after treatment. Counts from these 2 samples were combined to give 20 samples per tree for statistical analysis.

In a second experiment 3 rates of Dimilin 25% W.P. were applied at the pink bud stage in the same manner as above, but no surfactant was used. These treatments are listed in Table 2. The experimental plot in this trial consisted of 12 trees in randomized complete blocks containing 4 treatments per block, with 3 single-tree replicates per treatment. Living larvae were counted on 10 leaf clusters selected at random from each tree 9 days after treatment.

In a third experiment, methoxychlor, naled and Permethrin sprays with and without surfactant were applied in the pink bud stage. This trial also included an untreated control and a control spray containing surfactant only. Treatments were not replicated. Living larvae

Table 1. Number of living *Operophtera* larvae per leaf cluster on apple treated with various materials at the tight cluster bud stage.

Treatment	Rate of formulation per 100 litres	Larvae per Cluster [1,2]
Permethrin 50% E.C.	19 ml	0.20 a
Permethrin 50% E.C.	37 ml	0.52 ab
Acephate 75% S.P.	68 g	0.78 ab
Endosulfan 4 E.C.	124 ml	0.92 abc
Surfactant spray only	30 ml	1.10 abc
Diazinon 50% E.C.	124 ml	1.17 abc
Malathion 50% E.C.	249 ml	1.47 abcd
Methoxychlor 25% E.C.	498 ml	1.53 abcd
Imidan 50% W.P.	100 g	1.60 abcd
Imidan 50% W.P.	200 g	1.60 abcd
Naled 9.6 E.C.	124 ml	1.88 abcd
Acephate 75% S.P.	131 g	2.05 abcde
Thuricide HPC (*Bacillus thuringiensis*)	498 ml	2.38 bcde
Trichlorfon 50% S.P.	299 g	2.88 cdef
Thuricide HPC	996 ml	3.22 cdef
Dipel W.P. (*Bacillus thuringiensis*)	124 g	3.92 ef
Dipel W.P.	248 g	4.20 ef
Resmethrin 0.84% a.i. per litre	-	4.27 f
Control (untreated)	-	8.40 g

[1] Mean of 3 replicates.

[2] Values followed by the same letter are not significantly different at p = .05 (Duncan 1955).

were counted on 10 leaf clusters selected at random from each tree 5 days after treatment.

Data from the first two experiments were analyzed using a nested analysis of variance. Treatment means were compared using Duncan's Multiple Range test (Duncan 1955; Zar 1974). Data from treatments in the third experiment were analyzed by a two-way analysis of variance with replication.

Table 2. Number of living Operophtera larvae per leaf cluster on apple treated with Dimilin at the pink bud stage.

Treatment	Rate of formulation per 100 litres	Larvae per cluster [1,2]
Dimilin 25% W.P.	25 g	0.73 a
" " "	50 g	0.50 a
" " "	100 g	0.33 a
Control	-	3.00 b

[1] Mean of 3 replicates.

[2] Values followed by the same letter are not significantly different at p = .05 (Duncan 1955).

RESULTS AND DISCUSSION

In the first experiment, larval infestations were reduced by all treatments compared to the untreated control (Table 1). Permethrin, acephate, endosulfan, diazinon, malathion, methoxychlor, Imidan, naled and sprays containing surfactant only were most effective. Resmethrin, trichlorfon and the Dipel and Thuricide formulations of *B. thuringiensis* were less effective.

In this experiment, unsprayed trees and those sprayed with *B. thuringiensis*, trichlorfon and Resmethrin were completely defoliated within 48 days after the tight cluster bud stage. Trees sprayed with Permethrin were undamaged. Most of the remaining materials may have provided better protection from partial defoliation if a second spray had been applied, in the pink bud stage.

In the second experiment, Dimilin reduced

Table 3. Number of living Operophtera larvae per leaf cluster on apple treated with various materials at the pink bud stage.

Treatment	Rate of formulation per 100 litres	Larvae per cluster
Methoxychlor 25% E.C.	498 ml	0.2
Methoxychlor 25% E.C. + surfactant	498 ml 30 ml	0.5
Naled 9.6 E.C.	124 ml	0.1
Naled 9.6 E.C. + surfactant	124 ml 30 ml	0
Permethrin 50% E.C.	19 ml	0
Permethrin 50% E.C. + surfactant	19 ml 30 ml	0

larval infestations significantly 9 days after treatment in the pink bud stage (Table 2). There were no differences in control among the 3 dosage rates tested.

In the first experiment we obtained excellent control with sprays containing surfactant only. For this reason we suspected an interaction between surfactant and insecticides in the remaining treatments in that trial. However, the results of the third trial using sprays with and without surfactant showed no interaction (Table 3). There was also no significance between larval counts from the untreated control and those from trees sprayed with surfactant only.

The variable results obtained with surfactant sprays may be due to a difference in larval age groups between the first trial and the third trial. In the first trial there was a higher proportion of early-instar larvae which might have been more sensitive to surfactant sprays. However, the relatively light defoliation of trees treated with surfactant only in the first trial is unexplained. Further studies are therefore required to reach any valid conclusions on the efficacy of surfactant sprays for control of winter moth and Bruce spanworm.

ACKNOWLEDGEMENTS

We wish to thank the University of Victoria for providing the experimental site for these trials, and J. C. Arrand, B.C. Ministry of Agriculture, for his advice and assistance.

REFERENCES

Cuming, F. G. 1961. The distribution, life history and economic importance of the winter moth, **Operophtera brumata** (L.) (Lepidoptera: Geometridae), in Nova Scotia. Can. Ent. 93: 135-142.

Eidt, D. C. and D. G. Embree. 1968. Distinguishing larvae and pupae of the winter moth, **Operophtera brumata**, and the Bruce spanworm, **O. bruceata** (Lepidoptera: Geometridae). Can. Ent. 100: 536-539.

Gillespie, David R., Thelma Finlayson, Norman V. Tonks and Douglas A. Ross. 1978. Occurrence of the winter moth, **Operophtera brumata** (Lepidoptera: Geometridae), on southern Vancouver Island, British Columbia. Can. Ent. 110: 223-224.

McMullen, R. D. 1973. The occurrence and control of the Bruce spanworm in the Okanagan Valley, 1972. J. Ent. Soc. B.C. 70: 8-10.

Pree, D. J. 1976. Effects of two insect growth disruptors, PH 6038 and PH 6040, on the winter moth, **Operophtera brumata** (Lepidoptera: Geometridae). Can. Ent. 108: 49-52.

Sanford, K. H. and H. J. Herbert. 1966. The influence of spray programs on the fauna of apple orchards in Nova Scotia. XX. Chemical controls for winter moth, **Operophtera brumata** (L.), and their effects on phytophagous mite and predator populations. Can. Ent. 98: 991-999.

THE EFFECT OF ROOT WEEVILS (COLEOPTERA: CURCULIONIDAE) ON YIELD OF FIVE STRAWBERRY CULTIVARS IN BRITISH COLUMBIA

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ABSTRACT

To determine the effect of root weevils on strawberry yield, 5 strawberry cultivars: Totem, Shuksan, Northwest, Cheam and BC-25 were infested in the field with 2 or 8 adults per plant of 1 of 4 species of root weevils: the black vine weevil, *Otiorhynchus sulcatus* (F.); the strawberry root weevil, *O. ovatus* L.; the obscure strawberry root weevil, *Sciopithes obscurus* Horn; and the woods weevil *Nemocestes incomptus* (Horn). There were no significant differences in yield between weevil infestations in the first cropping season. In the second year plants in the plot infested with 8 *O. sulcatus* per plant produced significantly less fruit than those in all other infestations. Within this plot Totem and Cheam produced significantly more fruit than the other cultivars. In the third year most of the other weevil-infested plots produced significantly less fruit than the uninfested plot. The plot with 2 *N. incomptus* per plant was the most severely damaged in the third season. The cultivars Totem and Cheam were usually the most tolerant to all weevils. Northwest and BC-25 were the most susceptible to all weevils. The tolerance of Totem to attack by the main root weevil species, *O. sulcatus*, is probably related to the ability of the plant to produce and regenerate a large supply of roots.

INTRODUCTION

The criteria for selecting parent plants in a strawberry breeding program include resistance or tolerance to major pests. In British Columbia several species of root weevils attack strawberry plants (Cram and Neilson 1975). This paper presents the results of a 3-year yield study of the 5 strawberry cultivars: Totem, Shuksan, Northwest, Cheam and BC-25 when they were subjected initially to 0, 2 or 8 adults per plant of 1 of the 4 species of root weevils: the black vine weevil, *Otiorhynchus sulcatus* (F.); the strawberry root weevil, *O. ovatus* L.; the obscure strawberry root weevil, *Sciopithes obscurus* Horn; or the woods weevil, *Nemocestes incomptus* (Horn).

METHODS

Nine strawberry plots were planted in May, 1971, 2 plots for each weevil species and 1 for no weevils. For each plot, 5 virus-free plants of each of the 5 cultivars were set out in 5 rows, 50 cm apart within and between rows in a randomized Latin square design. All blossoms were removed during this period of establishment and all runners were removed as they appeared.

To confine the flightless adults of root weevils an effective barrier was devised that utilized 4 mil black polyethylene plastic (Fig. 1A). A 1-m wide strip of the plastic was draped over a 6-mm diameter polyline that had been stretched over and stapled to 15-cm high cedar stakes. The lower edges were covered with soil on each side to anchor the plastic. Both sides of the plastic were then sprayed with polytetrafluorethylene ('Fluon' dispersion GP2). Adults were unable to climb this slippery vertical surface. This barrier was installed immediately after the plants were set out and was effective for the 37 months of this study.

Adult weevils collected from strawberry fields, except *S. obscurus* which were from rhododendron, were placed within the barriers at either 2 or 8 per plant as follows: *O. sulcatus* on July 30, *O. ovatus* on August 6, *S. obscurus* on August 13 and *N. incomptus* on September 3, 1971. Periodic observations indicated that the adults were successfully established. No herbicides, insecticides, fungicides or fertilizers were applied.

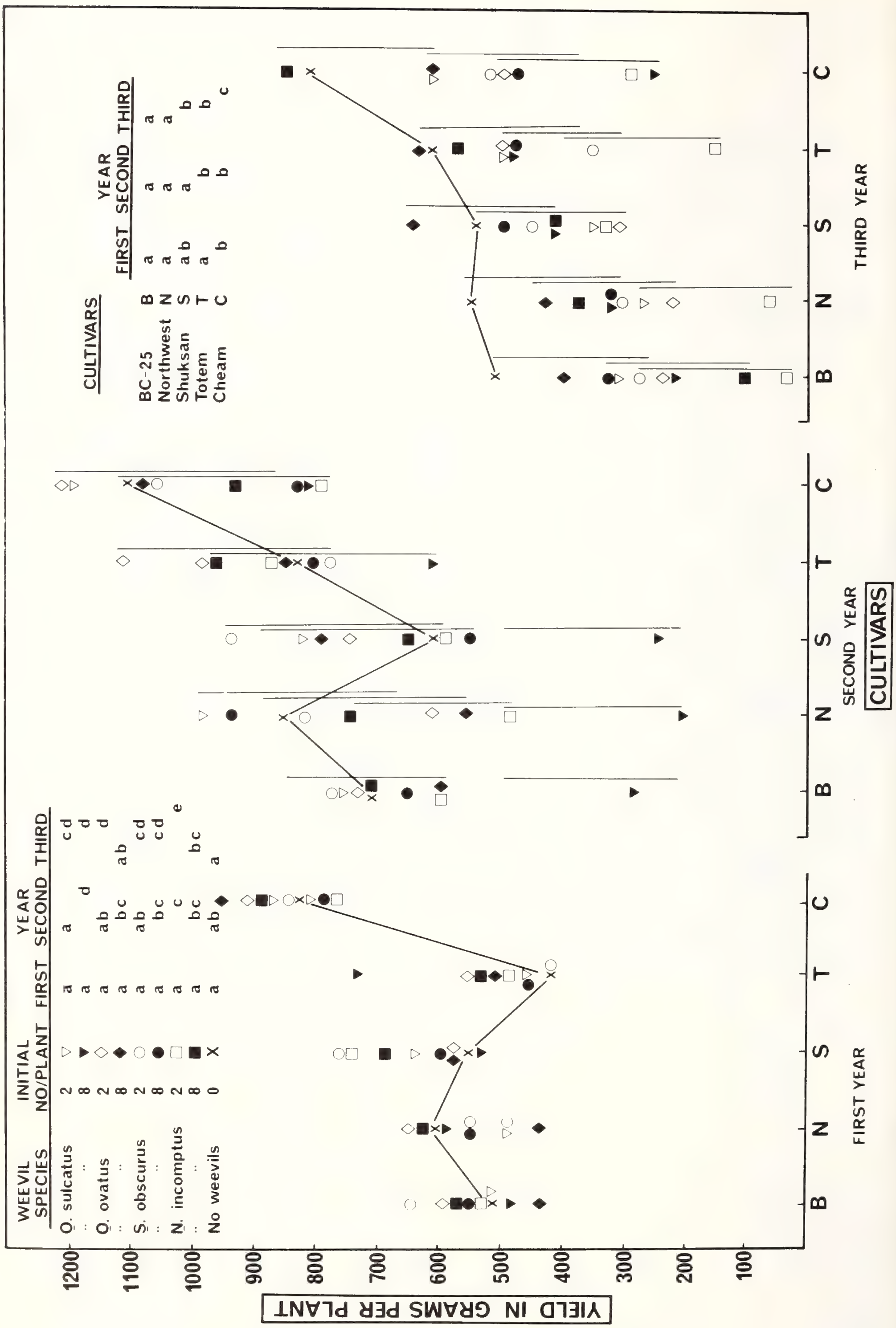
The total yield of all fruit from each plant was recorded for each of 3 years.

Fig. 1A. Construction of plastic barriers to contain and exclude flightless root weevil adults. B. Damage to strawberry cultivars during the second picking season when plants were initially infested with 8 **O. sulcatus** adults per plant. The plot with no weevils is in the immediate background.

RESULTS AND DISCUSSION

In the first cropping season the plants grew luxuriously. There were no significant yield differences between plots but there were significant differences between cultivars. Cheam significantly outyielded Totem, Northwest and BC-25, but not Shuksan (Fig. 2). However, Cheam was highly susceptible to fruit rot and had 24 percent rot; the other cultivars had only 10-12 percent rot.

In the second year the effect of *O. sulcatus* was evident. Where 8 *O. sulcatus* per plant had been added all the plants were smaller than normal and showed signs typical of weevil larval damage to their roots (Fig. 1B). The yields from all other infested plots were not significantly reduced. In the plot with 8 *O. sulcatus* per plant, the yield of the cultivars Totem and Cheam were not significantly reduced but BC-25, Northwest and Shuksan were signifi-


YIELD IN GRAMS PER PLANT
CULTIVARS
FIRST YEAR
SECOND YEAR
THIRD YEAR
WEEVIL SPECIES
INITIAL NO/PLANT
YEAR
FIRST SECOND THIRD
O. sulcatus
O. ovatus
S. obscurus
N. incomptus
No weevils
BC-25 B
Northwest N
Shuksan S
Totem T
Cheam C

cantly reduced over plants with no weevils (Fig. 2). In the same year the effect of 2 *N. incomptus* per plant became evident on BC-25, Northwest and Shuksan. In fact, all cultivars were more severely damaged by 2 *N. incomptus* per plant than by 8. Possibly the larger number of adults resulted in crowding that induced the weevils to leave the shelter of the plants and succumb to attempts at escape from the barriered plot, whereas, with only 2 per plant they may have settled under the plants and oviposited normally.

In the third year the trend to lower yields in plots with initially lower populations of adults was even more pronounced. The effect of 2 *N. incomptus* per plant was striking, causing severe damage on all cultivars. *O. ovatus* and *S. obscurus* at either level did not usually reduce yields significantly even by the third season. There were only 3 cases where yield of cultivars in infested plots exceeded the yield in the plot with no weevils (Fig. 2) and there were several cases where weevil damage significantly lowered yields.

The overall yield of Cheam was significantly higher than for Shuksan or Totem, which were in turn significantly higher than BC-25 and Northwest. Since Cheam is very susceptible to fruit rot, the choice of preferred parentage for breeding for weevil tolerance is between Totem or Shuksan. Totem could be judged superior to Shuksan on the basis of its second crop performance when subjected to a high population of *O. sulcatus* which is the most prevalent and most damaging species in this area. The ability of Totem to withstand attack may be related to its ability to produce a prolific root system.

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REFERENCES

Cram, W. T. and C. L. Neilson. 1975. Recognition and life history of the major insect and mite pests of berry crops in British Columbia. B.C. Dept. of Agric. publ'n.

Fig. 2. Yields for 3 years from 5 strawberry cultivars grown together in each of 9 barriered plots infested initially with 0, 2 or 8 adults per plant of 4 different species of root weevils. For each year the yields from the plot with no weevils are joined. Treatments enclosed by the same vertical line are not significantly different. In the legends, treatments or cultivars that have the same letter are not significantly different according to Duncan's multiple range test at P = .05.

EMERGENCE OF PREDATOR AND PARASITES OF THE WHITE PINE WEEVIL, *PISSODES STROBI* (COLEOPTERA: CURCULIONIDAE) FROM ENGELMANN SPRUCE[1]

T. J. D. VanderSar[2]

ABSTRACT

Adult insects of 13 species emerged from 153 leaders of Engelmann spruce attacked by *Pissodes strobi* at two British Columbia locations. The most abundant species was the dipteran, *Lonchaea corticis*, a scavenger and predator of immature *P. strobi.* The most important primary parasites that attack 4th-instar larvae and pupae were the hymenopterans, *Dolichomitus terebrans nubilipennis, Bracon pini, Eurytoma pissodis,* and *Rhopalicus pulchripennis.* Competition for suitable hosts appears greatest between the two last-named species, since females exhibited agonistic behaviour when searching for oviposition sites.

INTRODUCTION

Detailed studies have been carried out by Harman and Kulman (1967 and 1968) of the insect fauna associated with the successful attack and brood establishment of the white pine weevil, *Pissodes strobi* Peck, in leaders of eastern white pine, *Pinus strobus* L. Less extensive work has been done on infestations in Engelmann spruce, *Picea engelmannii* Parry (Stevenson, 1967). Little is known, however, of the mechanisms that the parasites might employ to minimize competition for suitable white pine weevil hosts and to synchronize their emergence with the host's life cycle. My observations on Engelmann spruce populations had indicated that most of the parasite species overwintered in the damaged leaders from which *P. strobi* had emerged the previous autumn. This paper reports the sequence of emergence of the parasite complex in the spring, and indicates the temporal partitioning of the parasite species in their utilization of the weevil hosts under field conditions.

METHODS AND MATERIALS

One hundred fifty-three dead terminals of young, open-grown Engelmann spruce attacked by *P. strobi* in 1976 were collected on May 6 and 7, 1977. Most of the leaders (132) were collected from Kootenay National Park, B.C., and the remainder from Glacier National Park, B.C., 640 km northwest of the initial collection site.

Each leader was put into a polyethylene bag and maintained in the laboratory at 20-24°C. The number and species of insects that emerged from each leader was recorded daily. Hymenopteran insects were held in small rearing cages to study inter- and intra-specific agonistic behaviour, whereas dipterans were identified and released after examination of the leaders. The number of emergence holes of weevils in the periderm of each leader were counted to assess the field emergence of adults from these leaders in autumn 1976.

RESULTS AND DISCUSSION

Table 1 shows the numbers and species of insects that emerged from the 153 leaders including species new to Engelmann spruce. The most abundant insect was a dipteran, *Lonchaea corticis* Taylor, a scavenger and predator of immature *P. strobi* (Harman and Kulman, 1967), particularly of pupae (R.I. Alfaro, pers. comm.). Construction of chip cocoons by 4th-instar weevil larvae in preparation for pupation may have adaptive significance not only to prevent desiccation, but also as a physical deterrent to predation by *L. corticis*. The principal parasite species were hymenopterans: *Dolichomitus terebrans nubilipennis* Viereck, *Eurytoma pissodis* Girault, *Bracon pini* Muesebeck, and *Rhopalicus pulchripennis* Crawford. Harman and Kulman (1967) and Stevenson (1967) verified that these four hymenopterans are primary parasites of white pine weevils infesting eastern white pine and Engelmann spruce, respectively. Stevenson (1967) recovered significant numbers of the braconid, *Eubadizon strigitergum* Cushman, and the ichneumonid, *Helcostizus rufiscutum* Cushman from Engelmann spruce leaders attacked by *P. strobi* in Kootenay National Park, B.C.; nevertheless, these two primary parasites were not recovered in the present study. Stevenson (1967) did not, however, specify their peak emergence periods.

The status of the remaining insect species listed in Table 1 is less well known, although Harman and Kulman (1967) report that *Pseudoeucoila* sp. is itself a parasite of *L. corticis.* Little is known of the general biology of

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Table 1. Insect species that emerged during May 10 - June 13, 1977, from 153 Engelmann spruce leaders naturally attacked by the white pine weevil, Pissodes strobi, in 1976 at two British Columbia locations, 640 km apart.

Species	Status	Glacier National Park		Kootenay National Park	
		Total No. of insects	% leaders infested (N=21)	Total No. of insects	% leaders infested (N=132)
DIPTERA					
Lonchaea corticis ‡	scavenger/predator	102	57.1	1,869	81.8
*Rhexoza sp.**	undetermined			28	1.5
*Oscinella sp.** ‡	"			11	5.3
HYMENOPTERA					
Dolichomitus terebrans nubilipennis ‡	primary parasite			65♂, 34♀	25.0
Eurytoma pissodis ‡	"			75	20.5
Bracon pini ‡	"			12♂, 11♀	5.3
Rhopalicus pulchripennis ‡	"	1	4.8	18	8.3
*Pilinothrix sp.**	undetermined	28	42.9	105	10.6
*Pediobius sp.** ‡	"			4	0.8
*Pseudoeucoila sp.** ‡	parasite of *L. corticis*			2	1.5
*Diadegma sp.**	undetermined			1	0.8
*Platygaster sp.**	"			1	0.8
*Cyrtogaster sp.**	"			1	0.8

‡ Species previously reported from leaders of eastern white pine attacked by P. strobi (Harman and Kulman, 1967).

* Species not previously reported from leaders of Engelmann spruce attacked by P. strobi.

Pilinothrix sp. which has not previously been reported from conifer terminals attacked by *P. strobi.*

Associated insects emerged from 90% of the spruce leaders collected in Kootenay National Park, but only 35% of these leaders bore evidence of successful emergence by weevils in the previous autumn. Comparable data from Glacier National Park indicated that weevils had emerged from 38% of the spruce leaders, whereas associated insects emerged from 67%. In both locations, the emergence of white pine weevils from attacked and killed spruce leaders was low, with a mean of only one adult per leader based on the count of emergence holes. These data suggest that entomophagous insects play a pivotal role in regulating the population of the weevils. Particularly important is *L. corticis* because each predator larva commonly attacks more than one immature weevil to complete its development (R.I. Alfaro, pers. comm.). The four species of primary parasites are probably of relatively minor importance in the regulation of weevil populations.

Figures 1-5 show the emergence over 28 days of *L. corticis* and four primary parasites from the spruce leaders. The median emergence date for *L. corticis* was May 16, but the primary parasite species combined had a bimodal emergence pattern. The median emergence dates for *D. terebrans nubilipennis* and *B. pini* were May 11 and 12, respectively. Stevenson (1967) reported that *D. t. nubilipennis* emerged in the field during a 4-week period from late May to June. Although early instar weevil larvae are present in attacked host leaders in June, oviposition by *D. t. nubilipennis* is delayed until July when 4th-instar larvae are available. Among the four primary parasites, only *D. t. nubilipennis* is morphologically adapted to oviposit alongside deep-lying *P. strobi* larvae that have constructed pupation chambers within the pith of the leader (Stevenson, 1967).

The median emergence dates for *R. pulchripennis* and *E. pissodis* were May 30 and June 1, respectively. Of particular interest was the agonistic behaviour, both inter- and intraspecific, which I observed between these two similar-sized parasites. In a rearing cage, mated females of both species were observed attempting to oviposit into the wooden surfaces although no spruce leaders or white pine weevils were present. When two females of the same or different species met on this substrate, one or both adopted a characteristic threat posture in which both the abdomen and prothoracic legs were raised and the wings held over the

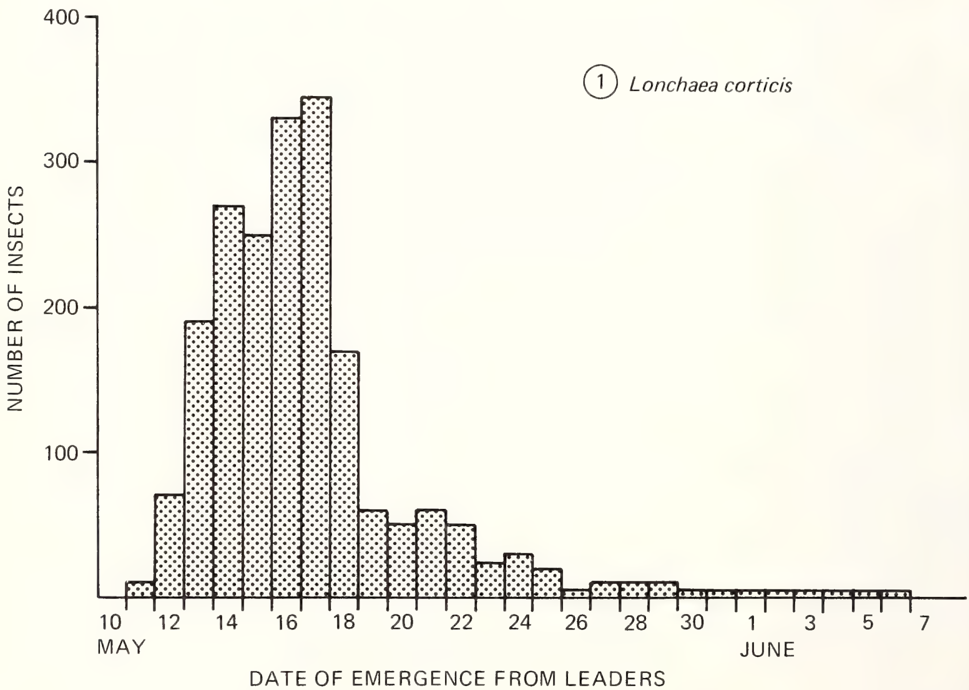
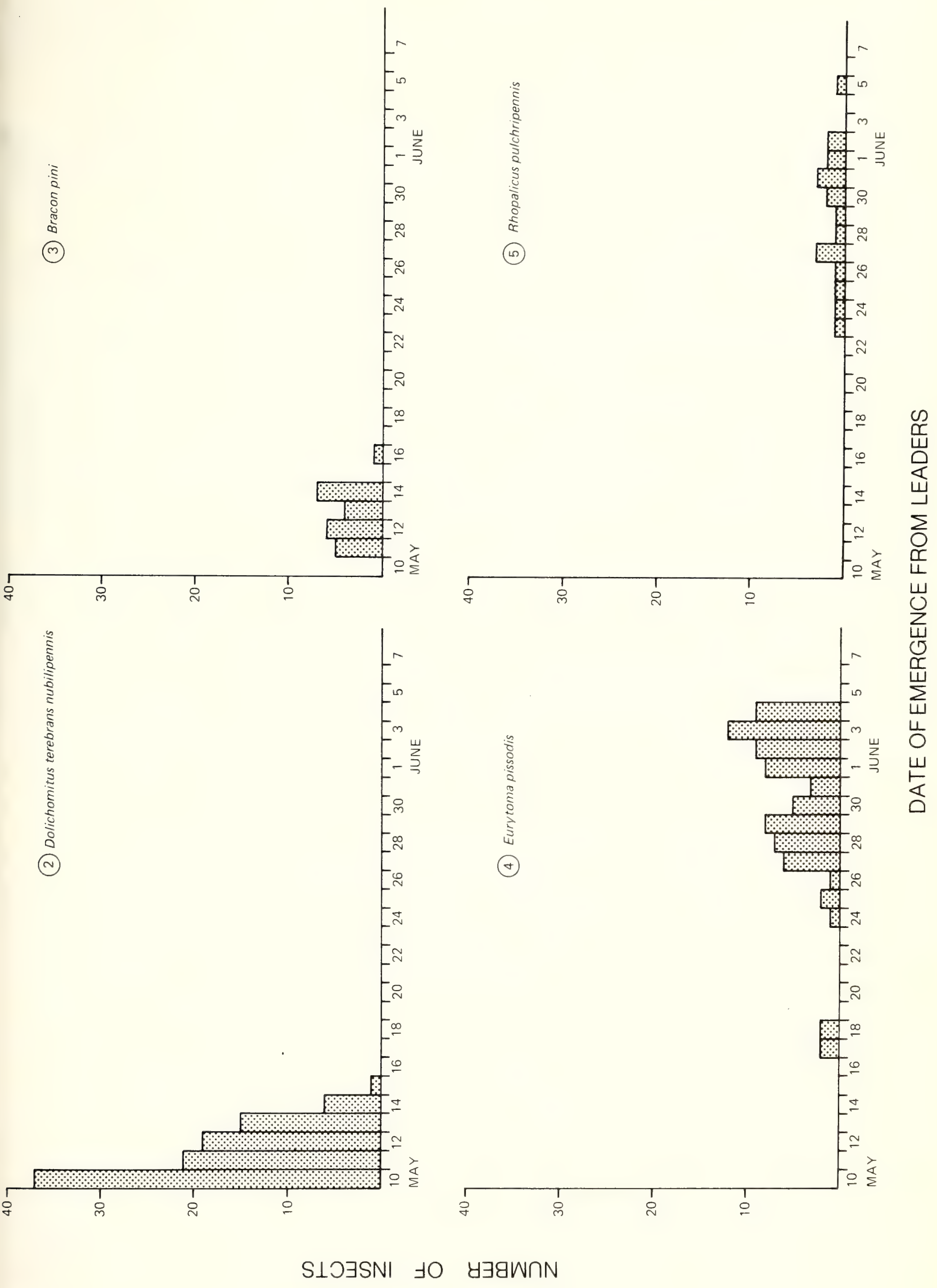


Figure 1. Daily emergence of *Lonchaea corticis* during May 10 - June 6, 1977, from Engelmann spruce leaders naturally attacked by **Pissodes strobi** in 1976 at two locations in British Columbia, 640 km apart.



Figures 2-5. Daily emergence of 4 species of primary, entomophagous hymenoptera during May 10 - June 6, 1977, from Engelmann spruce leaders naturally attacked by Pissodes strobi in 1976 at two locations in British Columbia, 640 km apart.

abdomen in a V-shape. Rapid butting contests would sometimes ensue until one or the other female retreated. More frequently, the threat posture deterred the advance of an approaching female, but several intances of butting were followed by grappling. Beaver (1967) reported similar agonistic behaviour in pteromalids competing for food resources or oviposition sites. *R. pulchripennis* and *E. pissodis* also compete for scolytid hosts such as *Dendroctonus monticolae* Hopkins (Bushing, 1965). Agonistic behaviour between these competing parasite species is likely to promote dispersal of the gravid females in the field.

ACKNOWLEDGEMENTS

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REFERENCES

Beaver, R. A. 1967. Hymenoptera associated with elm bark beetles in Wytham Wood, Berks. Trans. Soc. British Entomol. 17: 141-150.

Bushing, R. W. 1965. A synoptic list of the parasites of Scolytidae (Coleoptera) in North America north of Mexico. Can. Entomol. 97: 449-492.

Harman, D. M., and H. M. Kulman. 1968. Biology and natural control of the white pine weevil in Virginia. Ann. Entomol. Soc. Amer. 61: 280-285.

Harman, D. M., and H. M. Kulman. 1967. Parasites and predators of the white-pine weevil, **Pissodes strobi** (Peck). Univ. Maryland, Nat. Res. Inst. Contrib. 323, 35 pp.

Stevenson, R. E. 1967. Notes on the biology of the Engelmann spruce weevil, **Pissodes engelmanni** (Curculionidae: Coleoptera) and its parasites and predators. Can. Entomol. 99: 201-213.

THE DISTRIBUTION OF *TANYPTERYX HAGENI* (ODONATA:PETALURIDAE) IN BRITISH COLUMBIA

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ABSTRACT

In British Columbia the petalurid dragonfly *Tanypteryx hageni* (Selys) is considered to be rare. A record in 1977 extends its known range almost to 51°N latitude. The record also disputes the belief that *T. hageni* normally is restricted to subalpine habitats. In the northern parts of its range it appears to occur naturally at sea level.

INTRODUCTION

Tanypteryx hageni (Selys) is the only western North American representative of the primitive dragonfly family Petaluridae. The family has a distribution so limited and disjunct that the nearest relatives of *T. hageni* are *T. pryeri* Selys in Japan and *Tachopteryx thoreyi* (Hagen) in eastern North America.

Tanypteryx hageni ranges from southwestern British Columbia south through the mountains to California and Nevada (Cannings and Stuart, 1977). American localities are discussed in Kennedy (1917), Whitney (1947), Smith and Pritchard (1956), Svihla (1959) and Paulson and Garrison (1977). In Washington and Oregon the larvae are known to inhabit

mountain bogs at high altitudes where they burrow in wet muck and mosses associated with springs (Svihla, 1959). Larvae have never been found in British Columbia.

By 1976, *T. hageni* had been recorded from only four localities in British Columbia (Scudder *et al.*, 1976): Black Mountain, North Vancouver (1080 m), 9 Aug. 1931 (H. B. Leech): Liumchin Creek, Cultus Lake (150 m), 8 Jul 1934 (W. E. Ricker); Hell's Gate, near Yale (150 m), 30 Aug 1938 (W. E. Ricker); and Diamond Head, Garibaldi Park (1000 m), Jul 1969 (R. H. Carcasson).

All these localities are within the Cadcade Mountains or the extreme southern Coast Mountains of southwestern British Columbia. The Black Mountain and Diamond Head localities are in subalpine forest at 1000 m or higher. These habitats are similar to those at high altitudes reported for *T. hageni* in the United States. Occurrences of this insect at lower elevations, such as the Liumchin Creek and Yale records, always have been considered accidental (Whitehouse, 1941; Walker, 1958).

A recent distribution record for *T. hageni* suggests that these low-altitude records are not exceptional. The location is the mouth of the Ahnuhati River on Knight Inlet, 50°52'N latitude, about 250 km northwest of Vancouver or about 230 km northwest of the previous most northerly record of the species. Two specimens, a male and a female, were captured on 20 and 21 Jul 1977. Each was salvaged by Mr. Kevin Lloyd after it had been caught and killed by a pet housecat. The specimens were deposited in the Spencer-Entomological Museum, University of British Columbia.

The dragonflies apparently were attracted to a muddy area on the beach where water gently flowed over it from the cliffs above. Five or six other large black and yellow dragonflies were sighted along the banks of the Ahnuhati River. Possibly some of these were *Cordulegaster dorsalis* and not *T. hageni*.

This is an important record because the dragonflies apparently were residents of the coastal western hemlock forest at sea level and not merely strays from the mountains above. Evidently, in the northern part of its range, *Tanypteryx hageni* is not restricted to high elevations, for of the six specimens from British Columbia, four were from elevations of 150 m or lower. As suspected by Ricker (pers. comm.), at low elevations these dragonflies may develop in muddy or mossy seepages like those which larvae are known to inhabit in subalpine environments to the south. This habitat occurs along streambanks and in other cool, damp locations in lowland forests. The species is probably distributed more extensively to the north in British Columbia than was previously recognized and may not be so rare as was once supposed.

ACKNOWLEDGEMENTS

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REFERENCES

Cannings, R. A. and K. M. Stuart. 1977. The Dragonflies of British Columbia. B.C. Prov. Mus. Handbook No. 35, Victoria.

Kennedy, C. H. 1917. Notes on the life history and ecology of the dragonflies (Odonata) of central California and Nevada. Proc. U.S. Nat. Mus. 52:483-635.

Paulson, D. R. and R. W. Garrison. 1977. A list and new distributional records of Pacific Coast Odonata. The Pan-Pacific Entomologist 52:147-160.

Scudder, G. G. E., R. A. Cannings and K. M. Stuart. 1976. An annotated checklist of the Odonata (Insecta) of British Columbia. Syesis 9:143-162.

Smith, R. F. and A. E. Pritchard. 1956. Odonata, pp. 106-153 in R. L. Usinger, ed., Aquatic Insects of California. Univ. of California Press, Berkeley.

Svihla, A. 1959. Life history of *Tanypteryx hageni* Selys (Odonata). Trans. Amer. Ent. Soc. 85:219-232.

Walker, E. M. 1958. The Odonata of Canada and Alaska. Vol. 2. Univ. of Toronto Press, Toronto.

Whitehouse, F. C. 1941. British Columbia dragonflies (Odonata) with notes on distribution and habits. Amer. Midl. Nat. 26:488-557.

Whitney, R. C. 1947. Notes on *Tanypteryx hageni*. Ent. News 58:103.

THE MOSQUITOES OF BURNABY LAKE BRITISH COLUMBIA

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ABSTRACT

Ten species were found in a survey of the mosquitoes of the Burnaby Lake area; they included a small breeding population of *Aedes aloponotum*, a species not recorded in British Columbia since 1919. *Aedes aboriginis* was more numerous and troublesome. *Aedes sierrensis* and *Mansonia perturbans*, which bite both in the open and in houses, were less common, but because they are unaffected by the usual larval control techniques, are potential nuisance species in the area. *Aedes cinereus* and *Culiseta morsitans* were abundant, but the former bit only when disturbed and the latter did not bite humans.

INTRODUCTION

Burnaby Lake, near Vancouver, is the shallow drainage area of a once extensive peat-filled bog that drains slowly into the Fraser River. The general public and naturalists make considerable use of the area which is now a bird sanctuary. A narrow margin of marsh and woodland is preserved as a nature park.

The water level of the lake is controlled by a dam installed in 1923, and until recently the area was inaccessible, so that the mixed woodland and marsh have probably not changed much since 1921 when Hearle (1926) concluded a 3-year survey of the mosquitoes of the lower Fraser valley. However, most of the surrounding forested area within flight range of mosquitoes is now cleared and developed, leaving the lake populations isolated.

METHODS

Immature mosquitoes were collected from breeding sites and adults were sampled from swarms or as they came to bite. When females were numerous, standard counts were made of the number of mosquitoes landing on the front of the trousers between waist and knees, for two 1-min periods separated by 5 min (Agriculture Canada, 1972).

RESULTS

Ten species, representing the five genera of mosquitoes so far found in British Columbia, were collected around the lake. The immature stages that were collected are listed by habitat in Table I. Their biology is described in more detail below.

Anopheles punctipennis (Say): - This species was collected only in the larval stage. It was not numerous compared with other species in the same habitat and was never observed biting or resting under bridges or culverts where I have usually found it in late summer in other areas.

Aedes aboriginis Dyar: - This is the most numerous biting species and the most troublesome to humans. Larvae were found as early as mid-April in clearings and at the margins of the woodland in pools that ranged from the size of a horse's hoofprint to more than 10 m in diameter. Few adults were seen for about two weeks after they had emerged from the pupae. Several swarms of up to 20 males were seen in late May and early June 3-15 m above the ground, at the tips of branches on the lee or north side of broadleaf maples and cottonwoods. Females bit readily from late afternoon to at least an hour after sunset, when observations were discontinued. Females were present in clearings in wooded areas and in gardens at least 1 km from the nearest known breeding site. A landing rate of more than 5/min was measured at sunset in a picnic area about 400 m from a breeding site.

Aedes aloponotum Dyar: - Four large mosquitoes with pale banded tarsi and an orange brown scutum were taken in the late afternoon and evening between May 16th and July 12th, 1977. These proved to be the first specimens of *A. aloponotum* recognized in the province since Hearle's survey (Hearle, 1926). A systematic search in May 1978 of potential breeding sites, upwind of the area where the adults were collected, yielded two pupae associated with many larvae of *A. cinereus* in grass-lined pools 25 m from the main creek that feeds the lake. These were identified at emergence, on May 15th, as *A. aloponotum*. The first adults biting in 1978 were taken on June 3rd, in the same area as those found in 1977.

Aedes cinereus Meigen: - This was the most numerous aedine mosquito encountered. Larvae were dense in open grassy pools at the margin of the woodland and the lake and in shallow pools within the wood in which reedmace and burr-reed were growing. Apart from one reference to a cloud of males found in late afternoon

TABLE 1. Immature mosquitoes found round Burnaby Lake, by habitat.

Habitat	Species	Month	Stage
Ditches:			
outside woodland, sluggish	*Ca. incidens*	April - Oct.	E, L, P[2]
road and railway drainage	*C. pipiens*	July - Oct.	E, L, P
	An. punctipennis	June - Aug.	L
Woodland pools:			
dead leaf bottom	*A. aboriginis*	April - May	L, P
	Ca. inornata	May - July	L, P
peat	*Ca. morsitans*	April - Aug.	L, P
Pools in open:			
dead grass bottom	*A. aloponotum*	May	P
	A. cinereus	April - May	L, P
peat bottom[1]	*Ca. morsitans*	April - July	L, P
Stagnant channels:			
connected with lake	*Ca. morsitans*	April - Aug.	L, P
Lake:			
openings in vegetation mats fringing lake[1]	*Ca. morsitans*	June - Sept.	L, P

[1]These sites were sampled in February, the remainder only between April and October.
[2]Abbreviations: E, eggs; L, larvae; P, pupae.

(Edwards, 1932), swarming does not appear to have been described in this species. In late May and early June, I observed one large swarm in the same region, on several evenings just after sunset. It consisted of at least 100 males swarming less than 1 m from the ground over horsetails. Females flew into the swarm, often after biting the observer. Mating occurred at a rate between 5 and 10/min. Females did not appear to seek human hosts actively but did not hesitate to bite when disturbed in the afternoon or evening. Adults were only seen in undisturbed flight within about an hour of sunset.

Aedes sierrensis (Ludlow): - Immature stages and their preferred breeding site, i.e. water-filled tree holes, were not found. From about 20 females that bit the observer between June and September, three were caged individually and laid fertile eggs. One male was collected an hour before sunset hovering around the observer, confirming several previous observations that males are attracted to hosts and mate with females as they fly in to bite (Curtis, 1957). During the summer, several females were found biting in the house.

Culex pipiens L.: - Larvae and pupae were found in the open in stagnant drainage ditches, flooded vehicle tracks and artificial containers. Swarms of about ten males were found on several evenings over Douglas spirea bushes at the margin of the lake, from mid June to July. Later in the season this species swarms over the south walls of houses and buildings. No mating was seen in any of the swarms and no females were seen to bite outdoors. Females of this species enter houses in late August and September and a high proportion appear to take blood meals during the night.

Culiseta incidens (Thomson): - Egg rafts, larvae and pupae were found over a wide area in drainage ditches and in some artificial containers. Adult females were occasionally found under the eaves of houses and garages during the summer and autumn but these did not bite when placed in a tube over the observer's arm. No adult males of this species were found.

Culiseta inornata (Williston): - Larvae and pupae breed in deep pools in shaded woodland. Adults that appeared to be freshly emerged were found resting on moss beside one such pool in May. On two occasions a pair was *in copula*. Females occasionally bit in the woodland but were more numerous and appeared to be more aggressive near the lake.

Culiseta morsitans (Theobald): - This is the most abundant mosquito. Larvae were found in almost every still pool with brown peaty water including pools in floating mats of vegetation at the edge of the lake. No larvae were found in known breeding areas before March, although they overwinter in this stage in Europe (Marshall 1938). Several breeding sites were frozen solid in early January 1978, and the deeper pools were covered with 10 - 20 cm of ice. Despite the abundance of immature stages, only one swarm of males was seen at sunset in late June. About 10 males flew in an extended figure-of-eight about 1 m in a north-south direction among the leaves and branches of a cascara tree 2 m above the ground. Only two

females were taken in flight at the margin of the lake. Neither they nor any reared females could be persuaded to take human blood.

Mansonia perturbans (Walker): - Females bit in the woodland from mid-June to August in the afternoon and evening. Although several dozen clumps of reedmace were uprooted, washed and examined, no immature stages were found. From late June to September, females bit in the evening inside a house 1 km from the lake. No males were seen.

DISCUSSION & CONCLUSIONS

The most significant finding is the rediscovery of *A. aloponotum*. Wood (1977) described how this species was lost in synonymy for some 30 years and points out that Canadian material in the National collection consists of "a few females . . . from the lower Fraser Valley, most in poor condition", none of which was collected since the 1920's. Wood identified two of the females captured while biting in 1977 as *aloponotum* and this prompted a systematic search for its breeding site in 1978. The pupae were collected on May 13th, in a pool about 400 m from where the adults were caught.

The earliest that any female *Aedes* bit was about 2 weeks after the majority had emerged from the breeding sites I sampled. During this period, however, two female *aboriginis* were observed on flowers of wild crabapple. This supports the observations of Service (1972) and others, that in several species, both sexes feed on nectar for a few weeks before the females disperse for blood meals.

Hearle commented (1926) that "during three years . . . very few specimens (of *C. pipiens*) have been collected. It would appear that this species has been introduced comparatively recently". In the 1970's I have found *C. pipiens* as numerous as *Ca. incidens* which it appears to be displacing in artificial and temporary breeding sites.

My observations on the biting habits of *A. aboriginis* and *sierrensis* also differ from Hearle's. He considered that the former was "neither very vicious nor persistent" and that the latter "are timid in approaching human beings". Around Burnaby Lake both species are now bold and persistent in their attacks on man and one wonders if their behaviour may have changed after 50 years of exposure to this relatively new and abundant host.

Of 21 species that Hearle (1926) collected in numbers in the valley, 13 would be expected to occur in the habitats around Burnaby Lake; of these 13, at least nine are still present. It appears that the isolation of the lake has had little effect on the number of species. *Culiseta morsitans* is the only species that Hearle did not collect, and it is surprising that it was so numerous at what appears to be the southern limit of its range (Curtis 1967).

Only *A. aboriginis* appears to be a nuisance around Burnaby Lake, occasionally invading a nearby picnic site with a landing rate of more than 5/min. Repellents seem to be an adequate solution for the public as they are for the naturalists walking the trails in the evening. *A. sierrensis* and *M. perturbans* could be a problem to homeowners in warm and wet summers because both species readily enter houses. Neither is affected by normal larval control procedures and insect screens may be the only effective solution.

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I thank Dr. D. M. Wood of the Canada Agriculture Biosystematics Research Institute, Ottawa, for identifying *A. aloponotum* and for his encouragement in my search for its immature stages. Thanks are also due to several members of my family who acted as attractants for female mosquitoes. The survey was made during a Sabbatical leave from Simon Fraser University.

REFERENCES

Agriculture Canada, 1972. Planning an anti-mosquito campaign. Pub. No. 1485, 15 pp.

Curtis, L. C. 1967. The mosquitoes of British Columbia. Occasional Papers, B.C. Provincial Museum, No. 15, 90 pp.

Edwards, F. W. 1932. *Anopheles algeriensis,* Theobald (Diptera, Culcidae) in N Norfolk. J. Ent. Soc. S. Eng. 1: 26.

Hearle, E. 1926. The mosquitoes of the lower Fraser Valley, British Columbia, and their control. National Research Council of Canada Report No. 17, 94 pp.

Marshall, J. F. 1938. The British Mosquitoes. British Museum, London, 341 pp.

Service, M. W. 1972. Flight activities of mosquitoes with emphasis on host seeking behaviour. In: Symposium on biting fly control and environmental quality. Ed. A. Hudson: 125-132. Defence Research Board of Canada Pub. No. DR 217.

Wood, D. M. 1977. Notes on the identities of some common Nearctic Aedes mosquitoes. Mosq. News 37: 71-81.

FRUIT TREE LEAFROLLERS (LEPIDOPTERA) AND PARASITES (HYMENOPTERA) INTRODUCED IN THE VANCOUVER DISTRICT, BRITISH COLUMBIA

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ABSTRACT

Introduced European species comprised 5 of the 6 most common and 8 of the 11 total species of leafrollers found on apple and pear in the Vancouver district in 1977. Parasitism was low. Two of the leafroller parasites, *Apanteles ater* (Ratz.) and *A. longicauda* (Wesm.), and a gracilariid parasite, *Achrysocharoides zwölferi* (Delucchi), are European species new to North America.

LEAFROLLERS

One, *Choristoneura rosaceana* (Harr.), of the six most common species of leafrollers found on apple and pear in the Vancouver district in 1977 is native to North America. The other five were introduced to North America from Europe. They are: *Croesia holmiana* (L.), found in North America for the first time in this survey and recorded elsewhere (Doganlar and Beirne, in preparation); and *Hedia nubiferana* (Haw.), *Spilonota ocellana* (Den. and Schiff.), *Pandemis cerasana* Hbn., and *Archips rosanus* (L.), all already known to inhabit the district.

Other species of leafrollers found on apple and pear were: *Acleris comariana* (Zell.), previously recorded only as a strawberry pest in B.C. *Archips podana* (Scop.), and *Acleris variegana* (Schiff.), all introduced species; *Pandemis canadana* Kft., a native species; and *Acleris robinsoniana* (Forbes), whose status as a Holarctic or Nearactic species appears to be obscure. These species were found in only small numbers.

Eight of the 11 species of leafrollers mentioned above are non-natives that were introduced accidentally into North America, 5 of them apparently first into southwestern British Columbia or the Pacific Northwest. Only one of the introduced species, *A. rosanus*, has so far spread into the Okanagan Valley, where it was first found in 1971 as an apple pest in 1972. Others of the introduced species may become important pests when they colonize the Okanagan Valley or the fruit growing regions of the interior of Washington and Oregon, as their distributions abroad indicate that they could survive the climate there, at least in irrigated situations.

PARASITES

Two of the three species of hymenopterous parasites that were reared from two or more of the six most common species of leafrollers (none was reared from the other five) are apparently accidentally-introduced European species. They are: *Apanteles ater* (Ratz.), reared from *P. cerasana*, *A. rosanus*, *C. rosaceana*, and *H. nubiferana* and not recorded previously from North America; and *Apanteles longicauda* (Wesm.), reared from *H. nufiberana* and *C. rosaceana* and also not recorded previously from North America.

Ascogaster quadridentata Wesm., reared from *S. ocellana*, was deliberately introduced from England into the Lower Fraser Valley in the 1940's as a biological control agent of the pea moth, *Laspeyresia nigricana* (Steph.), itself an accidentally introduced species. The morphologically identical form known as *A. carposapsae* Vier was introduced into B.C. from Ontario in the 1930's as a biological control agent of the codling moth, *L. pomonella* (L.), and became established. It is not yet known which of these forms is the parasite of *S. ocellana*.

Spilonota ocellana was also parasitized by *Agathis dimidiator* (Nees), a European species probably accidentally introduced into Eastern North America and apparently not recorded previously from the West.

The European eulophid *Achrysocharoides zwölferi* (Delucchi) was reared from the gracilariid *Phyllonorycter blancardella* Forb. during this survey. It also has not been recorded previously from North America. At Burnaby, British Columbia it has three generations a year, overwinters as a pupa inside the larval web of its host, and was reared from nearly 10 percent of the host larvae collected.

Other parasites reared from the leafrollers were: *Meteorus argyotaeniae* Joh., from *H. nubiferana*, *C. rosaceana*, and *S. ocellana*; *Enytus* sp. (or spp.), from *C. holmiana* and *H. nubiferana*; *Tranosema* sp. (or spp.), from *C. rosaceana* and *C. holmiana*; and *Macrocentrus iridescens* French, *Scambus* (*S.*) *decorus* Walley, *Ischnus inquisitorius atriceps* (Cress.), *Apanteles* sp., and *Miscogaster* sp., from *C. rosaceana*.

The native species of leafroller, *C. rosaceana*, had 9 species of parasites and a total parasitism of under 10 percent. The five introduced

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of the six most common species had one to four species each. Total parasitism averaged 5 percent and ranged from less than 1 percent in *C. holmiana* to about 8 percent in *H. nubiferana*.

None of the parasites identified in this survey was the same as any of those identified from a survey of parasites of apple leafrollers on various foodplants in the Okanagan Valley, B.C., in 1972 (Mayer and Bierne, 1974. *J. ent. Soc. B.C.* 71: 22-25).

"While this paper was in press *Phyllonorycter blaucardella* Forb. was found to be a different and undescribed species."

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AN ERRONEOUS REFERENCE TO *AËDES AEGYPTI* (L.) IN BRITISH COLUMBIA

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There is an unfortunate error in the standard monograph "*Aëdes aegypti* (L.) the yellow fever mosquito" by Sir. S. Rickard Christophers (1960).

In dealing with the northern limits of its distribution, Christophers states: "There is, however, a record (Good, 1945) stating that *A. aegypti* used to occur in British Columbia, but has not been recorded for thirty years". This record is included in his Figure 1, a map showing the world distribution of the species and in his Table 1, the recorded northern limits of its distribution. However, British Columbia is not mentioned in Good's paper, which is a list of mosquitoes of the *District* of Columbia. The list does include *A. aegypti*, collected by J. Carrol on August 3rd 1901.

The present northern limit of *A. aegypti* on the west coast is Baja California although interceptions are occasionally made by quarantine officials in the state of California (Bohart and Washino 1978).

Summer temperatures in both North and South America (July & January respectively) are lower on the west coast than at corresponding latitudes on the east coast. Ignoring the erroneous British Columbia record, the present distribution of *A. aegypti* in the Americas corresponds closely with the 21 C summer isotherm.

REFERENCES

Bohart, R. M. and Washino, R. K. 1978. Mosquitoes of California. 3rd Edition, University of California, Berkeley.

Christophers, Sir. S. R. 1960. Aëdes aegypti (L.) the yellow fever mosquito: its life history, bionomics and structure. Cambridge Univ. Press.

Good, N. E. 1945. A list of mosquitoes of the District of Columbia. Proc. Entomol. Soc. Wash. 47: 168-197.

NATURAL ENEMIES OF BUDWORMS, *CHORISTONEURA* SPP. (LEPIDOPTERA: TORTRICIDAE), ON DOUGLAS FIR NEAR YALE, BRITISH COLUMBIA, IN 1977

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ABSTRACT

Two species of *Choristoneura* were reared from an infestation on Douglas fir in the Yale-Spuzzum area in 1977: *occidentalis* Free. and an apparently undescribed species. Larvae with parasites averaged 47.6 percent and increased from 14.5 percent in larvae collected early in May to 74 percent in those collected early in July. Pupae with parasitism were 52 percent. Three well-known species of budworm parasites comprised 85 percent of the parasites reared. Eight other species of Lepidoptera were reared from the Douglas fir. One of these, *Dioryctria pseudotsugella* Munroe, becomes a predator on budworm prepupae and pupae when all the foodplant foliage has been consumed by budworms.

INTRODUCTION

The controversial decision, subsequently revoked, to spray the infestation of budworm in the Fraser Canyon district with chemical pesticides in 1977 was made apparently without adequate evaluation of the importance of parasites and predators that might contribute to the collapse of the outbreak but could be harmed by the pesticides. Surveys were made in the Yale-Spuzzum area of the Canyon in the spring and early summer of 1977 to obtain some indications of the identities and importance of the parasitic insects.

METHODS

Douglas fir was the only kind of tree seen to be regularly infested heavily; it comprises 0.4 to 68 percent of the trees per acre in that area (data from G. Williams). About 5,000 budworm larvae and pupae were obtained. Collections were made on 7 May, 13 June, and 7 July by taking infested branches from trees. A total of 15 Douglas fir, 20-50 cm in diameter, were felled and sampled but some collections were from small firs of about 5 cm diameter.

Choristoneura larvae were selected at random from the branches collected on 7 May and 13 June. Ten groups of 20 from each date were reared separately, for a total of 400. All of the 110 larvae and 603 pupae collected on 7 July were reared individually. Parasites that emerged were sent for identification to the Biosystematics Research Institute, Canada Agriculture, Ottawa. The remainder of the material collected was mass-reared to see if other species of Microlepidoptera were present.

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MICROLEPIDOPTERA REARED

The budworm infestation had been assumed to be of the Western budworm *Choristoneura occidentalis* Free. In fact it included a second species of *Choristoneura* that is probably new and unnamed. *C. occidentalis* was the more abundant of the two by a ratio of ten to one.

Eight other species of Microlepidoptera were reared from the Douglas fir, as follows: *Griselda radicana* Hein., was the most common; *Dioryctria pseudotsugella* Munroe, which is sometimes a predator on the budworms (see below); *Argyrotaenia provana* Kft., *A. dorsalana* Dyar, *Spilonota ocellana* D. & S., *Zeiraphera hesperiana* Mut. and Free.; and two as yet unidentified species of Gelechiidae. These species did not appear to be sufficiently abundant individually or collectively to be a significant pest problem.

PARASITISM AND PARASITES

Totals of 472 individuals and nine species or species-groups of parasites emerged from the 1121 separately-reared *Choristoneura* larvae and pupae (Table I). An average of 47.6 percent of the larvae and 53.2 percent of the pupae produced parasites. Actual pupal parasitism may have been higher, since parasites had already emerged from some host pupae by the time the collections of 7 July were made. These were not included in the count. Three species, *Glypta fumiferanae, Apanteles fumiferanae,* and *Winthemia fumiferanae,* comprised 85 percent of all the parasites reared. They are well-known parasites of budworms, as their names indicate; the eastern spruce budworm is *C. fumiferana* and the species in B.C. was formerly classified under that name.

All the species listed in Table I and 14 additional species emerged from the mass-reared material that included the additional

TABLE 1. Parasites that emerged from separately-reared Choristoneura spp. collected on different dates in 1977 near Yale, B.C.

7 May: 200 2nd and 3rd instar larvae, 29 parasites: 14.5 percent parasitism.
Parasite species: **Apanteles fumiferanae** Vier., **Glypta fumiferana** (Vier.) and **Diadegma** sp.

13 June: 200 3rd and 4th instar larvae, 41 parasites: 20.5 percent parasitism.
Parasite species: **A. fumiferanae, G. fumiferanae, Mesochorus tachypus** Holm., which was a secondary parasite on **A. fumiferanae**, and **Gelis tenellus** (Say), which was a secondary parasite on **M. tachypus**.

7 July: 117 4th and 5th instar larvae, 87 parasites: 74.4 percent parasitism.
Parasite species: **A fumiferanae, G. fumiferanae, Winthemia fumiferanae** Tot., and **Itoplectis quadricingulata** (Prov.), as a secondary parasite of **G. fumiferanae.**

7 July: 603 pupae, 315 parasites: 52.2 percent parasitism.
Parasite species: **W. fumiferanae, Apechthis ontario** (Cres.), **I. quadricingulata**, as a primary parasite, and **Phaeogenes hariolus** (Cres.).

species of Lepidoptera. The additional species are: *Scambrus* (S.) *transgressus* (Holm.), *Mesochorus tachypus* Holmg., *Apanteles renaulti* Mason, *Microchelonus,* n. sp. near *isolatus, Ascogaster argentifrons* Prov., *Elasmus atratus* (How.), *Dicladocerus nearcticus* Yshm., *Polynema* sp., *Chrysocharis thomsoni* (Crawf.), two unidentified species of *Habrocytus, Pseudencyrtus* sp., and *Dendrocerus (Macrostigmia)* sp.

DISEASES

Proportions of the larvae or pupae that died without producing either moths or insect parasites were: 7 May collection, 14 percent; 13 June, 8 percent; 6 July, 24 percent of larvae and 10 percent of pupae. The causes of deaths were not identified, although many of the dead larvae contained a fungus. The incidence of disease in the reared material is not a reliable indication of its incidence in the field as diseases were not surveyed in the field and many deaths in the laboratory may have been a consequence of rearing conditions.

PREDATION BY A PYRALID

Predation was not surveyed in the field. In the laboratory larvae of the pyralid moth *Dioryctria pseudotsugella* were observed feeding on budworm prepupae and pupae at a rate of one or two per larva per day. Tests showed that, when given the choice, the larva prefers to feed on fresh foliage of Douglas fir and attacks budworms only if such foliage is not available. In the field *D. pseudotsugella* normally feeds on the new needle growth that is also eaten by the budworms but, as it appears about a month later than the budworms and develops more slowly, the budworms may consume all its potential food supply so that if it is to survive its only alternative is to feed on the budworms.

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EGG DISPERSION IN THE LARCH CASEBEARER, *COLEOPHORA LARICELLA* (LEPIDOPTERA: COLEOPHORIDAE), IN NORTHERN IDAHO[1]

M. W. BROWN[2] AND D. L. KULHAVY[2]

ABSTRACT

During 1976, a total of 3122 eggs of the larch casebearer, *Coleophora laricella*, was found on 2937 needles. Of these needles, 94% had 1 egg, 5.8% had 2 eggs, and 0.2% had more than 2. The dispersion pattern fitted a negative binomial distribution (k = 0.498). There were significantly more eggs (α=0.01) on insolated than on shaded branches. The dispersion pattern is due primarily to the heterogeneity of environmental factors affecting oviposition.

INTRODUCTION

Egg dispersion has not been examined in previous biological and ecological investigations of the larch casebearer, *Coleophora laricella* (Hubner), the primary insect pest of western larch, *Larix occidentalis* Nutt. To sample a species adequately, it is necessary to know its initial dispersion. Our investigation was combined with a project to measure the pre-overwintering mortality of *C. laricella* (Brown 1976).

METHODS

Two larch casebearer populations were investigated in mixed coniferous stands having moderate to heavy infestations, in northern Idaho. Stand 1, 7 km northwest of Troy, Latah County, was in a *Thuja plicata/Pachistima myrsinites* habitat type (Daubenmire and Daubenmire 1968), with 18% (stems per ha) larch and at an elevation of 850-975 m. Stand 2, 35 km southwest of Lewiston, NezPerce County, was in an *Abies grandis/P. myrsinites* habitat type, with 45% (stems per ha) larch, and at an elevation of 1340-1365 m. Four circular 0.02 ha plots were located within each stand. One branch within 0.5 - 2.0 m of the ground was selected on each of six trees per plot. On each plot, three of the branches were shaded, three were exposed. Branches were selected prior to oviposition to minimize sampling bias. Each sample branch consisted of 100 spur shoots, counted from the terminal end including secondary branches, or 100 casebearer eggs, whichever came first. Eggs were sampled four times beginning 1 July 1976 to ascertain the pattern of dispersion. The first two samples were made biweekly, and at four week intervals thereafter.

A two-tailed paired t-test was used to compare egg population density between the exposed and shaded branches. For this comparison, we averaged the population data for the three branches with similar exposure on the same plot. Dispersion of the eggs was analyzed by methods outlined by Southwood (1966), including a Chi-square test for a Poisson (random) distribution, the coefficient of dispersion, and Morisita's Index. The individual spur shoot was used as the unit on which the calculations were based. As the dispersion of many forest insects is aggregated and can be described by a negative binomial model (Waters 1955), the parameter k was calculated for the eggs. The statistic U was used to see how well the larch casebearer egg dispersion fitted the negative binomial as opposed to other models for aggregated distributions. The degree of contagion was measured using the mean crowding value (λ) based on the population mean and k.

RESULTS AND DISCUSSION

A total of 3122 eggs was recorded on 2937 needles. Of these, 2760 needles (93.97%) had one egg, 170 (5.79% had two eggs, 6 (0.21%) had three eggs and 1 (0.03%) had four eggs. The number of needles with more than 1 egg is lower than the value of 21% given by Denton (1964) but higher than that of Jagsch (1973). This implies a density-dependent relationship, since Denton worked with a larger population and Jagsch with a smaller population than we did. Similar to Miller and Finlayson (1977), we also found a significant difference ($\alpha = 0.01$) in egg densities between the exposed and shaded branches. The exposed branches averaged 105.92 eggs per 100 spur shoots, but the shaded branches only 44.62 eggs.

The dispersion of *C. laricella* eggs fits the negative binomial distribution and is highly aggregated. The calculated Chi-square value of 10,810.72 (significant χ^2df4547 = 4771.01, $\alpha = 0.01$) shows that dispersion does not follow a Poisson distribution and therefore is not truly random. The coefficient of dispersion (2.38), Morisita's Index (3.01) and k (0.498) all indi-

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cate a high degree of aggregation. Using the k value and mean number of eggs per spur shoot (0.686), the statistic U demonstrates that the dispersion pattern fits the negative binomial distribution. (If U ± S.E. encompasses 0, the negative binomial fits the data, the calculated $U = 2.8 \times 10^{-5}$, S.E. = 0.33.)

A λ value significantly less than 2 (Southwood 1966, Fig. 11, page 36), suggests that aggregation was due primarily to environmental rather than behavioral factors. Environmental factors that may contribute to aggregation of larch casebearer eggs include illumination (Schwenke 1958, Sloan 1965), ambient temperature (Quednau 1967), lushness of foliage (Sloan and Coppel 1965), or a combination of these factors. Gravid females are attracted to the well illuminated parts of the tree (Schwenke 1958, Sloan 1965). These are also more likely to maintain ambient temperatures in the optimum oviposition range of 21° to 27° C (Quednau 1967) for longer periods than are shaded branches. We also observed that exposed branches produced lusher foliage, which attracted gravid females (Sloan and Coppel 1965).

The aggregation of *C. laricella* eggs most probably involves the attraction of gravid females to lush, illuminated foliage. The clumping of eggs on both shaded and exposed foliage indicates that once a female finds the proper conditions for oviposition, she continues to oviposit in the same area, this resulting in the observed high degree of aggregation.

REFERENCES

Brown, M. W. 1976. A partial life table for the larch casebearer **Coleophora laricella** (Lepidoptera: Coleophoridae) with notes on egg dispersion, M.S. Thesis, Univ. of Idaho, Moscow, ID.

Daubenmire, R. and J. B. Daubenmire. 1968. Forest vegetation of eastern Washington and northern Idaho. Washington State Univ. Agric. Exp. Sta. Tech. Bull. 60. 140 pp.

Denton, R. E. 1964. The larch casebearer in western larch forests. Northern Rocky Mountain Region, A problem analysis. (unpub.) U.S. Dep. Agric. For. Serv. Intermountain Forest and Range Exp. Sta., Moscow, ID 24 pp.

Eidmann, H. H. 1965. Ecologic and physiologic studies on the larch casebearer, **Coleophora laricella** Hbn. (Eng. Transl.) Studia Forestalis Suecica. No. 32. 322 pp.

Jagsch, A. 1973. Population dynamics and parasite complex of the larch casebearer in the natural area of distribution of European larch. (Eng. Transl.) Z angew. Entomol. 73: 1-42.

Miller, G. E. and T. Finlayson. 1977. Distribution of **Coleophora laricella** (Lepidoptera: Coleophoridae) and its major parasites in the crowns of western larch in British Columbia. J. Entomol. Soc. British Columbia 74: 10-15.

Quednau, F. W. 1967. Notes on mating, oviposition, adult longevity, and incubation period of eggs of the larch casebearer, **Coleophora laricella** (Lepidoptera: Coleophoridae), in the laboratory. Can. Entomol. 99: 397-401.

Schwenke, W. 1958. Uber die Standortabhangigkeit des Massenwechsels der Larchenminiermotte, **Coleophora laricella** Hbn., und der Ahorneule, Acronyta aceris L. (Eng. Abstr.) Beitrz. Z. Entomol. 8: 241-290.

Sloan, N. F. 1965. Biotic factors affecting populations of the larch casebearer **Coleophora laricella** Hbn. in Wisconsin. Ph.D. Dissertation, Univ. of Wisconsin, Madison, Wisconsin. 193 pp.

Sloan, N. F. and H. C. Coppel. 1965. Ovisposition patterns and egg predation of the larch casebearer (**Coleophora laricella** Hbn.) in Wisconsin. Univ. Wisconsin Res. Notes 124. 4 pp.

Southwood, T. R. E. 1966. Ecological methods, with particular reference to the study of insect populations. Chapman and Hall. London.

Waters, W. E. 1955. Sequential sampling in forest insect surveys. Forest Sci. 1: 68-79.

Webb, F. E. 1953. An ecological study of the larch casebearer, **Coleophora laricella** Hbn. (Lepidoptera: Coleophoridae). (unpub.) Ph.D. Dissertation University of Michigan, Ann Arbor, Michigan. 210 pp.

PRE-OVERWINTERING MORTALITY IN THE LARCH CASEBEARER, *COLEOPHORA LARICELLA* (LEPIDOPTERA: COLEOPHORIDAE), ON WESTERN LARCH IN NORTHERN IDAHO.[1]

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ABSTRACT

During 1976, continuous sampling of the same population cohort showed a 68% mortality in the pre-wintering larch casebearer, *Coleophora laricella*, in northern Idaho. The major mortality factors were density-independent; these were: premature needle drop caused by the needle diseases *Meria laricis* and *Hypodermella laricis* (18%); non-viable eggs (10%); and dislodgment of the eggs from the branch (10%). Other factors were: predation, desiccation, ripening and fall of the needles, intraspecific competition, loss of larvae moving between needles, and larch-willow rust.

INTRODUCTION

The larch casebearer, *Coleophora laricella* (Hübner), is the primary insect pest of western larch, *Larix occidentalis* Nutt. Originally found only in the eastern European highlands on European larch, *L. decidua* Mill., *C. laricella* is now nearly Holarctic in distribution (Schindler 1968).

Although researchers have investigated the biology and ecology of *C. laricella* (Webb 1953, Eidmann 1965, Sloan 1965), and a life table was prepared in Austria by Jagsch (1973), little is known about pre-overwintering mortality in western North America. Limited data only are available on egg mortality from predation, dislogdment and failure of the eggs to hatch (Baird 1923, Sloan 1965, Denton 1972). Predation, fungi, desiccation, autumn needle fall and intraspecific competition cause mortality during the larval mining stage (Jung 1942, Webb 1950, Sloan 1965, Jagsch 1973).

The purpose of our study was to identify the mortality factors in the egg, mining and autumn casebearing stages of the larch casebearer, in northern Idaho.

METHODS

Two sampling areas were established in sapling stands of western larch with moderate to heavy casebearer infestations. Stand 1 was located 7 km northwest of Troy, Latah County, in a *Thuja plicata/Pachistima myrsinites* habitat type (Daubenmire and Daubenmire 1968); it had 18% (stems per ha) larch and ranged from 850 to 975 m elevation. Stand 2 was located 35 km southwest of Lewiston, Nez Perce County, in an *Abies grandis/P. myrsinites* habitat type; it had 45% (stems per ha) in larch and ranged from 1340 to 1365 m elevation.

Four circular 0.02-ha plots were located within each stand. One branch within 0.5-2.0 m of the ground was selected on each of six trees per plot. Three branches on each plot were exposed to the sun, the other three were shaded. Each sample branch consisted of 100 spur-shoots, counted from the terminal and including secondary branches, or 100 casebearer eggs, whichever came first. A barrier was erected at the end of the 100 spur shoots (or 100 eggs). The larch casebearers on these 48 branches constituted our population cohort. The branches were selected prior to oviposition to minimize sampling bias.

We sampled the same population cohort six times beginning 1 July 1976, to ascertain the degree and the cause of mortality in *C. laricella*. Counts were made on individual spur shoots to follow the development of individual casebearers. The first two samples were made biweekly, and at four-week intervals thereafter. Sampling continued until the first week of November when the larch needles had yellowed and begun to fall. By this time, nearly all the larvae had migrated to overwintering sites on the branch. Notes were made on the probable causes of mortality.

Our cohort samples differed from the samples used for other lepidopteran needle miners (Stark 1958, Jagsch 1973), in that we sampled a single cohort during the period, and thus avoided destructive sampling. Our method permitted the incorporation of more observational data and a more accurate accounting for the population decline.

Halfway through the sampling period one exposed sample branch was vandalized. Mortality of the mining and casebearing stages on the missing branch was estimated by averaging the mortality percentages from the other two exposed branches on the plot.

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TABLE I. Pre-overwintering mortality factors for the larch casebearer in northern Idaho, 1976.

Age Interval x	Number alive at beginning of x l_x	Factor responsible for d_x d_xf	Number dying during x d_x		d_x as percent of l_x $100q_x$	
Egg	3122	Non-viable				
		No-hatch	142		4.6	
		Empty	116		3.7	
		Abnormal	48		1.5	
		Total		306		9.8
		Predation		98		3.1
		Needle Cast		176		5.6
		Needle Rust		36		1.2
		Dislodged		10		0.3
		Unknown[1]		304		9.7
				930		29.7
Mining Larvae	2192	In-transit		245		11.2
		Needle Cast		380		17.3
		Needle Rust		17		0.8
		Intraspecific Competition		55		2.5
		Needle Drop		114		5.2
		Dead		71		3.2
		Unknown[2]		222		10.1
				1104		50.3
Fall Casebearing Larvae	1088	Needle Cast	19		1.8	
		Needle Drop	11		1.0	
		Dislodged	6		0.6	
		Dead	7		0.6	
		Unknown[3]	36		3.3	
			79		7.3	
Entering Winter	1009	Total Mortality	2113		67.7	

[1] Mostly dislodgment

[2] Mostly in-transit mortality

[3] Mostly needle drop and dislodgment

RESULTS

Approximately two-thirds (67.7%) of the cohort died between oviposition and the attainment of the overwintering stage (Table I). Nearly 30% of the eggs did not hatch for various reasons and of those that did, more than one-half of miners failed to form a case. More than 7% of those forming a case did not survive to winter. Density-dependent factors accounted for 4.9% mortality, whereas density-independent factors were responsible for 62.8% mortality (Table II).

Density-Independent Factors

Needle-cast fungi, *Meria laricis* Vuill. and *Hypodermella laricis* v. Tub., caused a decline of 18.4% in the cohort by inducing premature needle drop. *Meria laricis* was the more important. Nearly all branches were infected. Several branches, completely defoliated, had the entire resident casebearer population destroyed. Needle casts were most abundant in the lower crown.

Non-viable eggs, 9.8% of the cohort (29.7% of the eggs), were divided into three categories;

TABLE II. Summary of pre-overwintering mortality factors acting on the larch casebearer, northern Idaho, 1976.

Factor	Stage Affected[1]		No. Killed		Percent Mortality
Density-Independent					
Needle Cast	e,m,c		575		18.4
Non-viable	e				
No-hatch		142		4.6	
Empty		116		3.7	
Abnormal		48		1.5	
Total			306		9.8
In-transit	m		245		7.9
Needle Drop	m,c		125		4.0
Dead	m,c		78		2.5
Needle Rust	e,m		53		1.7
Dislodged	e,c		16		0.5
	e[2]		304		9.7
Unknown	m[3]		222		7.1
	c[4]		36		1.2
Density-Dependent					
Predation	e		98		3.1
Intraspecific					
Competition	m		55		1.8
Total	e,m,c		2113		67.7

1 e = egg stage, m = mining stage, c = casebearing stage

2 Mostly dislodgment

3 Mostly in-transit mortality

4 Mostly needle drop and dislodgment

no-hatch, empty and abnormal. No-hatch eggs had normal shape and color, but simply failed to hatch. Empty eggs were pale and translucent when first observed, apparently lacking normal contents. Abnormal eggs were either small and withered, or desiccated.

Mining and casebearing larvae still attached to the needles during autumn needle fall accounted for a 4.0% loss. Larvae in this category either failed to form a case or were attached to a needle rather than a branch for overwintering.

Larch-willow rust, caused by *Malampsora paradoxa* Diet. and Holw., caused a 1.7% mortality in the same manner as needle casts. This rust affected only the egg and early mining stages.

Some eggs and casebearing larvae were dislodged by mechanical disturbances. Much of the unknown egg mortality may have been due to dislodgment.

Miners that died while moving between needles (in-transit mortality) accounted for 7.9% of the cohort. This mortality factor, due to either dislodgment or desiccation, was estimated from mined-out needles without a larch casebearer nearby.

Larvae in their mines or cases, but not feeding between sample periods were recorded as dead. This mortality was caused by desiccation or diseases.

Density-Dependent Factors

We did not directly observe predation. Eggs placed in this category appeared healthy when first observed, but were pale and translucent at a later examination. Because of the similarity in appearance of these eggs and empty eggs, predators may have caused some of the mortality categorized as non-viable.

Intraspecific competition resulted when more than one egg hatched on the same needle. Usually only the larva located near the needle base survived. When more than one larva survived, one, or both, migrated to a fresh needle.

DISCUSSION

The high level of in-transit mortality is contrary to the findings of Webb (1953), who found little migration in the mining stage. We concluded that in-transit mortality was induced by: (1) dense aggregation of the eggs (Brown 1976), and (2) desiccation of the needles from diseases. The combined effect of these factors increased migration of the larvae which led to increased exposure and predation.

Dislodgment of eggs accounted for 0.3% of the observed mortality. However, including the unknown egg mortality, 8-10% of the cohort was lost in this manner.

The value of 3.1% predation (6.9% including eggs classified as empty) was considerably less than had been previously reported (15% by Webb 1950; 5-40% by Eidmann 1965; 22% by Sloan 1965; 16% by Denton 1972). Mites and true bugs were the most important predators, with a large red mite, *Bdella muscorum* Ewing, apparently the most important in Idaho (Denton 1972). Webb (1953) considered that predation was an important biological control factor of *C. laricella*. Predation was difficult to ascertain, but possible predators (spiders, predaceous mites, true bugs, and thrips, *Aeolothrips* sp.) were present on our sample branches.

Failure of the eggs to hatch was a major cause of mortality. Jagsch (1973) attributed egg mortality to hatching difficulties; Eidmann (1965) attributed it to disturbance in development of the embryo; or simply to infertility or non-viability. We divided egg mortality into three categories based on appearances (Table I).

Although less than one-third of our cohort survived to the over-wintering stage, the preoverwintering period is not considered critical for population regulation. Density-independent factors were primarily responsible for the population decline, and as Nicholson (1958) and Solomon (1957) state, population regulation can only come about through the action of density-dependent mortality factors. Quednau (1967) also concluded that regulating, natural control factors do not act upon the egg stage of the larch casebearer. Following the same population cohort, as we did, allowed for a more accurate accounting of mortality, than did destructive sampling, and with less disruption to the population.

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REFERENCES

Baird, A. B. 1923. Some notes on the natural control of the larch sawfly and larch casebearer in New Brunswick in 1922. Acadian Ent. Soc. Proc. Nova Scotia (1922) 8:158-171.

Brown, M. W. 1976. A partial life table for the larch casebearer, **Coleophora laricella** (Lepidoptera; Coleophoridae) with notes on egg dispersion. M.S. Thesis, Univ. of Idaho, Moscow, Idaho.

Daubenmire, R. and J. B. Daubenmire. 1968. Forest vegetation of eastern Washington and northern Idaho. Washington State Univ. Agric. Exp. Sta. Tech. Bull. 60. 104 pp.

Denton, R. E. 1972. Establishment of *Agathis pumila* (Ratz.) for control of larch casebearer and notes on native parasitism and predation in Idaho. U.S. Dep. Agric. For. Serv. Intermountain Forest and Range Exp. Sta. Res. Note INT-164. 6 pp.

Eidmann, H. H. 1965. Ecologic and physiologic studies on the larch casebearer, **Coleophora laricella** Hbn. (Eng. Transl.) Studia Forestalis Suecica. No. 32. 322 pp.

Jagsch, A. 1973. Population dynamics and parasite complex of the larch casebearer in the natural area of distribution of European larch. (Eng. Transl.) Z. angew. Ent. 73:1-42.

Jung, W. 1942. Contributions to the knowledge of the larch casebearer (**Coleophora laricella** Hbn.). (Eng. Transl.) Z. angew. Ent. 29:475-517.

Nicholson, A. J. 1958. Dynamics of insect populations. A. Rev. Ent. 3:107-136.

Quednau, F. W. 1967. Notes on mating, oviposition, adult longevity, and incubation period of eggs of the larch casebearer, **Coleophora laricella** (Lepidoptera: Coleophoridae), in the laboratory. Can. Ent. 99:397-401.

Schindler, U. 1968. Population change in a typical perennial forest pest, the larch casebearer. (Eng. Transl.) Z. angew. Ent. 61:380-386.

Sloan, N. F. 1965. Biotic factors affecting populations of the larch casebearer **Coleophora laricella** Hbn. in Wisconsin. (Unpub.) Ph.D. Dissertation, University of Wisconsin, Madison, Wisconsin. 193 pp.

Solomon, M. E. 1957. Dynamics of insect populations. A. Rev. Ent. 2:121-142.

Stark, R. W. 1958. Life tables for the lodgepole needle miner **Recurvaria starki** Free. (Lepidoptera: Gelechiidae). Proc. X Internatl. Cong. Ent. (1956) 4:151-162.

Webb, F. E. 1950. The biology of the larch casebearer **Coleophora laricella** Hubner in New Brunswick. (Unpub.) M.S. Thesis, University of Michigan, Ann Arbor, Michigan. 50 pp.

Webb, F. E. 1953. An ecological study of the larch casebearer, **Coleophora laricella** Hbn. (Lepidoptera: Coleophoridae). (Unpub.) Ph.D. Dissertation, University of Michigan, Ann Arbor, Michigan. 210 pp.

EXAMINATION OF DOUGLAS-FIR CLONES FOR DIFFERENCES IN SUSCEPTIBILITY TO DAMAGE BY CONE AND SEED INSECTS

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ABSTRACT

In 1974 and 1976, Douglas-fir cones from 51 clones and 150 clones, respectively, were collected and determinations were made of the percentage of seed damaged by the cone insects *Barbara colfaxiana, Contarinia oregonensis, C. washingtonensis* and *Megastigmus spermotrophus.* Although statistically significant differences in percentage of damaged seeds were detected among clones, these differences were not great enough to be of practical importance.

RÉSUMÉ

En 1974 et en 1976, dans respectivement 51 et 150 clones, les auteurs récoltèrent des cônes de Douglas et déterminèrent le pourcentage de graines endommagées par les Insectes *Barbara colfaxiana*, *Contarinia oregonensis*, *C. washingtonensis* et *Megastigmus spermotrophus*. Malgré que des différences statistiquement significatives de pourcentages de graines endommagées fussent détectées parmi les clones, les différences ne se révélèrent pas importantes en pratique.

Significant differences have been reported in cone insect attack among clones, i.e. a group of genetically identical plants derived asexually from a single individual (Snyder, 1972), in slash pine, *Pinus elliottii* Englm. var. *elliottii* (De Barr *et al.*, 1972; Merkel *et al.*, 1965). Thus the present study was conducted to determine if a similar situation is true in seed orchards on Vancouver Island, British Columbia. Fifty-one Douglas-fir clones were sampled in 1974 and 150 in 1976; only 35 of these were sampled in both years but none in 1975, because of a poor cone crop. Twenty cones were taken from each clone and, where possible, from five ramets, i.e. an individual member of a clone, per clone. Damage in percentage of seed per cone, was determined for four common Douglas-fir insect pests: the cone moth, *Barbara colfaxiana* (Kearfott); the cone gall midge, *Contarinia oregonensis* Foote; the cone scale midge, *C. washingtonensis* Johnson, and the seed chalcid, *Megastigmus spermotrophus* Wachtl.

The data were analyzed on the basis of percent damaged seeds per cone, after being transformed, to correct for heterogeneity of variance, to the limited arcsin. The means were compared using the Student-Neuman-Keuls' multiple range test, with extension suggested by Kramer for unequal replications (Steel and Torrie, Principles and Procedures of Statistics, 110-114. 1960).

Because of the size of the experiment (four insect pests x three orchards x 166 total clones) and because so few significant differences were detected, we have summarized the results verbally; the numerical data are available from the authors. The results showed that: damage by the cone moth and cone scale midge did not differ significantly among any of the clones within the same orchard; damage by the cone gall midge did not differ significantly among clones except for one clone which suffered more damage than the others in the same orchard; damage by the seed chalcid was significantly more severe for only two clones in the same orchard. Because the analyses showed only minor differences in extent of insect damage among clones, these differences were generally of no practical importance.

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REFERENCES

DeBarr, G. L., E. P. Merkel, C. H. O'Gwynn and M. H. Zoerb, Jr. 1972. Differences in insect infestation in slash pine seed orchards due to phorate treatment and clonal variation. For. Sci. 18: 56-64.

Merkel, E. P., A. E. Squillace and G. W. Bengston. 1965. Evidence of inherent resistance to *Dioryctria* infestation in slash pine. Proc. 8th South. Conf. For. Tree Improvement. pp 96-99, Savannah, Ga.

Snyder, E. G. 1972. Glossary for forest tree improvement workers. South. For. Expt. Sta. Forest Service, USDA, New Orleans, La.

LABORATORY EVALUATION OF *GEOCORIS BULLATUS*[1] AND *NABIS ALTERNATUS*[2] AS PREDATORS OF *LYGUS*[3,4]

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ABSTRACT

Adults of *Geocoris bullatus* were not effective predators against late nymphs and adults of *Lygus*, but adults of *Nabis alternatus* were effective against these stages. Both predators were effective against the young *Lqgus* nymphs. Males of *N. alternatus* were almost as successful as females against small prey but were less effective against the late stage *Lygus*.

INTRODUCTION

Since pest management programs are being developed for alfalfa grown for seed in central Washington (Johansen et al. 1976), there is a need to determine the impact of these 2 groups of predators on populations of *Lygus*. In the laboratory study reported here, we attempted to establish what life stages of *Lygus* are most vulnerable to predation by *Geocoris* and *Nabis* spp.

MATERIALS AND METHODS

Studies were conducted in pint-size cages (Tamaki and Butt 1977) containing an alfalfa bouquet made of 4-5 stems in bloom or of seed bearing terminals cut 7-10 cm long. Such heavily packed stems provided both food and shelter for the *Lygus* and also made a more natural environment than the near-empty cages or petri dishes commonly used as arenas for studies of predator-prey interaction. Although only 1 predator was added to each cage, the number of *Lygus* was varied according to the size of the predator and prey. The intent was always to provide more prey than the predator could consume.

Each treatment of a particular life stage of the predator or prey was tested 2 times, 10 replicates per test, and each test lasted 5 days. All cages were checked daily to determine the condition of the insects and for maintenance. Cages were kept on laboratory benches under daylight fluorescent lights (16-hr photophase) at an average temperature of 24°C (range 18-32°).

For each treatment with a predator, a corresponding treatment without predators but with the same number of *Lygus* of the same stage was established. We were thus able to determine a corrected rate of predation by determining *Lygus* mortality in both situations.

Geocoris bullatus and *Nabis alternatus* were the predators used because they were the most readily available species. They were collected in the field on alfalfa and red clover and from beneath the trees in an orchard. No work was conducted with the 1st instars of either *Geocoris* or *Nabis* because they were difficult to collect and equally difficult to observe. Lygus bugs were collected from seed-bearing lambsquarters, *Chenopodium album* L., and pigweed, *Amaranthus retroflexus* L., and were a mixture of *Lygus elisus* Van Duzee and *L. hesperus* Knight; *L. elisus* was predominant. We did not separate the collected nymphs so all are referred to as *Lygus* or lygus bug. During the collections, some field observations were made.

RESULTS AND DISCUSSION

Geocoris

Geocoris adults caged with large *Lygus*, either 4th- and 5th-stage nymphs or adults, consumed so few prey that the corrected mortality (Table 1) was probably all the result of laboratory conditions. In fact, *Geocoris* adults were not observed feeding on adult or late instar *Lygus* but were frequently observed feeding on young *Lygus*.

All other stages of *Geocoris* from 2nd-to 5th-stage nymphs did feed on young (2nd-3rd instars) *Lygus* nymphs.

Nabis

Since Perkins and Watson (1972) studied predation by *Nabis* nymphs in Arizona, we concentrated on the predation by the adult stage in our study (Table 2). *Nabis* adults consumed relatively few *Lygus* adults, but the rate was 3 times that of *Geocoris* adults. They also consumed more late-instar (5th and 4th) nymphs. However, *Nabis* adults consumed 14 times as many 2nd-stage *Lygus* nymphs as adult *Lygus*.

We also made a special test in which 5th-stage *Nabis* were caged with the 4th or 5th stages of *Lygus* so we could compare our results with those of Perkins and Watson (1972). Our 5th-stage *Nabis* consumed an avg of 0.41 ± 0.12 S.E. 5th-stage *Lygus* per day compared with 0.9 per day in Perkins and Watson's test or an avg of 1.33 ± 0.19 S.E. 4th-stage *Lygus* per day compared with 2.9 per day in their test. The data of Fye (1978),

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[1] Hemiptera: Lygaeidae

[2] Hemiptera: Nabidae

[3] Hemiptera: Miridae

[4] In cooperation with the College of Agriculture Research Center, Washington State University, Pullman 99164.

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TABLE 1. Predation rates (corrected) of life stages of *Geocoris bullatus* feeding on stages of *Lygus*.

Life stage of *Geocoris*	Life stage of *Lygus*	No. consumed per day (average ± S. E.)
Adult	Adult	.08 ± .05
Adult	4th-5th	.02 ± .02
5th	2nd-3rd	1.57 ± .20
4th	2nd-3rd	.89 ± .11
2nd-3rd	2nd-3rd	.47 ± .11

who also studied the feeding rates of *Nabis* on *Lygus* in *Arizona*, were likewise more in agreement with those of Perkins and Watson than with ours. Therefore, the consumption rates of *Nabis* in Washington were about ½ those reported by 2 groups of workers in Arizona. The difference could reflect geographic differences, species differences, or differences in temperature (constant temperatures of 25° and 28° C for Perkins and Watson and Fye, respectively, and our range from 18° to 32° with an avg of 24°C). However, we feel that the heavy foliage of alfalfa in the cages was probably the main cause of the lower efficiency of the predator. Thus our values may be more comparable to feeding rates in the field.

Nabis females consumed more prey than males (Table 3). However, the difference between the sexes was less when they were caged with smaller *Lygus* nymphs. Apparently, the male is almost as successful as the female against small prey but is less effective against larger prey.

TABLE 2. Predation rate (corrected) of adults of *Nabis alternatus* preying on stages of *Lygus*.

Life stage of *Lygus*	No. consumed per day (Average ± S.E.)
Adult	.23 ± .05
5th	1.09 ± .14
4th	2.08 ± .11
3rd	2.62 ± .30
2nd	4.41 ± .54

TABLE 3. Predation rate of adult male and female *Nabis alternatus* on life stages of *Lygus*.

Life stage of *Lygus*	Average no. of *Lygus* killed ♀ *Nabis*	♂ *Nabis*	% consumed by male
Adult	.43	.025	5
5th	1.52	.700	32
4th	2.72	1.820	40
3rd	3.40	2.565	43
2nd	5.66	5.300	48

CONCLUSION

Although adults of *Geocoris* occasionally prey on 4th, 5th, and adult stages of *Lygus*, this species is primarily a predator of the smaller nymphal stages of Lygus (1st-3rd instars). *Nabis* is an effective predator against large *Lygus* (4th, 5th and adults) but is more successful against smaller *Lygus*. The impact of *Geocoris* and *Nabis* on populations of *Lygus* therefore depends both on the number of predators and on the age distribution of the *Lygus* population.

Indexing Words:
Lygus
Geocoris bullatus
Geocoris pallens
Nabis alternatus
Predators
Biological control

REFERENCES

Fye, R.E. 1978. Analysis of cotton insect populations in southern Arizona: Impact of predators and other mortality factors. USDA Tech. Bull. (In press).

Johansen, C. A., E. C. Klostermeyer, A. H. Retan, and R. R. Madsen. 1976. Integrated pest management on alfalfa grown for seed. Wash. State Univ., Coll. Agric. and Coop. Ext. Serv. EM 3755, 8 p.

Perkins, P. V., and T. F. Watson. 1972. *Nabis alternatus* as a predator of *Lygus hesperus*. Ann. Entomol. Soc. Am. 65: 625-9.

Tamaki, G., and B. A. Butt. 1977. Biology of the false celery leaf tier and damage to sugarbeets. Environ. Entomol. 6: 35-8.

BUPRESTIDAE OF SOUTHERN VANCOUVER ISLAND

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ABSTRACT

This paper lists the Buprestidae known to occur on Southern Vancouver Island, British Columbia, with their hosts. Represented are the following tribes: Buprestini (15 spp.); Chrysobothrini (6 spp.); Acmaeoderini (1 sp.); and Agrilini (1 sp.).

INTRODUCTION

Southern Vancouver Island comprises that area of the island south of latitude 49.5°. This area includes two major biotic zones, the coastal forest and the gulf island lowlands (Cannings and Stuart 1977). These zones have moderate temperatures and abundant winter rain with a characteristic Vancouveran fauna which is noted for its diversity of geobious and hydrobious beetles (Hatch 1953).

References to the Buprestidae of Southern Vancouver Island are brief. They include those of Walker (1866), LeConte (1869), Holland (1888), and Evans (1957), but Hardy (1927, 1942) compiled an annotated list of his captures in the greater Victoria area with notes on host species.

This paper expands the work of Hardy to include capture records from the southern part of the island. Specimens examined came from the collections of the University of Victoria (UV), the British Columbia Provincial Museum (PM), the Pacific Forest Research Center (PF), and the Saanichton Research Station (S). Figures in parentheses represent the number of specimens in the collection. The identifications and classification used in this list follow Barr (1971). The place names may be found in the Gazetteer of British Columbia and are printed in boldface type.

Family Buprestidae
Subfamily Buprestinae
Tribe Buprestini

Chalcophora angulicollis LeC.: **Victoria**, 4-VIII-29, W. H. A. Preece, (S) (2); ?-VIII-33, W. Downes, (S) (1); **Errington**, 6 to 29-V-29, G. H. Larnder, (PM) (12); **Sidney**, 5-VI-27, A. W. Nicholls, (PM) (5); **Victoria**, 24-V-34, G. A. Hardy, new cut fir, (PM) (3); **Nanaimo**, Holland (1888); Walker (1866); LeConte (1869); **Wellington**, anonymous (1906); Hosts: *Pinus contorta*, *P. ponderosa*, *Abies grandis*, *A. concolor* and *Pseudotsuga menziesii* (Barr 1971).

Trachykele blondeli Mars.: **Errington**, 3-VII-51, G. H. Larnder, (PM) (1); **Shawnigan L.**, 30-V-26, G. A. Hardy, (PM) (1); Hosts: *Thuja plicata*, Cupressus and Juniperus (Barr 1971).

Trachykele nimbosa Fall: **Langford**, 2-VI-60, D. Evans, in flight, (PF) (1); Hosts: *A. grandis*, *A. concolor*, *A. magnifica* and *T. mertensiana* (Barr 1971); Possibly a new island record.

Dicerca tenebrosa Kby.: **Nanaimo**, Holland (1888); **Wellington**, anonymous (1906); Hosts: numerous coniferous spp. (Barr 1971).

Dicerca sexualis Cr.: **Victoria**, 23-VI-34, G. A. Hardy, on *A. grandis*, (PM) (10); **Departure Bay**, ?-VI-08, W. Taylor, (PM) (1).

Dicerca crassicollis LeC.: **Errington**, 5-VI-29, 21-III-40, G. H. Larnder, (PM) (17); LeConte (1869).

Dicerca tenebrica Kby.: **Mesachi L.**, 12-VII-67, R. Morley, on beach, (UV) (1); Possibly a new island record.

Poecilonota fraseri Chamb.: **Victoria**, 20-VIII-26, G. A. Hardy, on willow, (PM) (2); Evans (1957); Hosts: *Salix* spp. (Barr 1971).

Buprestis aurulenta L.: **Victoria**, 4-VIII-29, W. H. A. Preece, (S) (3); G. A. Hardy, (PM) (3); **Shawnigan L.**, 14-VII-09, (S) (1); **Errington**, 1-VI-29, G. H. Larnder, (PM) (6); **Sidney**, 26-V-25, G. A. Hardy, on new-cut fir, (PM) (11), **Millstream**, G. A. Hardy, (PM) (9); Walker (1866); LeConte (1869), **Nanaimo**, Holland (1888); Wellington, anonymous (1906); Hosts: *Pseudotsuga menziesii*, *Abies grandis*, *Pinus ponderosa*, *P. jeffreyi*, *P. labertiana*, *P. contorta* and *P. flexilis* (Barr 1971).

Buprestis langi Mann.: **Metchosin**, 23-VIII-29, W. J. R. Preece, (S) (1); **Duncan**, 20-VIII-70, K. J. R. Bartlett, on the ground, (UV) (1); **Victoria**, 3-VIII-67, R. Ring, in grass, (UV) (1); 20-VIII-68, J. M. Campbell, on ground, (UV) (1); Walker (1866); LeConte (1869); **Wellington**, anonymous (1906); Host: *P. menziesii* (Barr 1971).

Buprestis adjecta LeC.: **Errington**, 4-VIII-46, G. H. Larnder, (PM) (1); **Parksville**, 4-VIII-46, G. H. Larnder, (PM) (1); **Nanaimo**, 16-VIII-98, W. Taylor, (PM) (2); **Sidney**, 31-VII-25, W. C. Cornfield, (PM) (1); LeConte (1869), **Wellington**, anonymous (1906); Hosts: *P. ponderosa*, *P. jeffreyi*, *P. contorta* and *Picea engelmanni* (Barr 1971).

Buprestis rusticorum Kby.: **Saanich**, 6-VIII-wi, W. H. A. Preece, (S) (2); **Caycuse**, 3-VIII-62, E. D. A. Dyer, in flight, (UV) (1); **Mesachi L.**, 5-VII-68. R. Storey, (UV) (1); **Millstream**, 2-

VIII-25, G. A. Hardy, New-cut Douglas fir, (PM) (8); **Errington**, 28-VIII-28, G. H. Larnder, (PM) (7); Walker (1866); Hosts: *P. ponderosa*, *Pseudotsuga menziesii* and *Abies grandis* (Barr 1971).

Melanophila acuminata DeG.: **Nanaimo**, 22-VIII-99, A. W. Hanham, (PM) (1); **Duncan**, 10-VIII-18, A. W. Hanham, (PM) (1); **Nanaimo**, Holland (1888); Hosts: *Pinus* spp., *Abies* spp. and *Picea* spp. (Barr 1971).

Melanophila drummondi Kby.: **Sidney**, 24-VII-26, W. H. A. Preece, (S) (3); 25-V-25, G. A. Hardy, (PM) (7); Victoria, ?-V-71, R. Ring, (UV) (2); 3 to 10-VI-34, G. A. Hardy, new-cut fir, (PM) (13); **Errington**, 13-V-51, G. H. Larnder, (PM) (5); **Goldstream**, 3-VI-24, G. A. Hardy, (PM) (7); **Nanaimo**, Holland (1888); LeConte (1869); Hosts: numerous conifer spp. (Barr 1971).

Anthaxia aeneogaster Cast. et Gory: **Saanich**, 13-V-29, W. H. A. Preece, (S) (1); **Shawnigan L.**, 11-VI-29, W. Downes, (S) (1); **Errington**, 14-IV-51, G. H. Larnder, on dandelion, (PM) (7); **Victoria**, 14-V-27, G. A. Hardy, (PM) (2); Hosts: *Pinus* spp. (Barr 1971).

Tribe Chrysobothrini

Chrysobothris sylvania Fall: **Sidney**, 21-VI-25, W. H. A. Preece, on fresh-cut Douglas fir, (S) (1); **Millstream**, 2-VIII-25, G. A. Hardy, on new-cut fir, (PM) (1); Host: *Pseudotsuga menziesii* (Barr 1971).

Chrysobothris carinipennis LeC.: **Sidney**, 8-VIII-25, G. A. Hardy, new-cut Douglas fir, (PM) (3).

Chrysobothris pseudotsugae Van Dyke: **Sidney**, 2-V-26, W. H. A. Preece, on fresh Douglas fir, (S) (2); **Victoria**, 3-VII-34, G. A. Hardy, new-cut *Abies grandis*, (PM) (4); Host: *Pseudotsuga menziesii* (Barr 1971).

Chrysobothris femorata (01.): **Sidney**, 21-VII-25, W. H. A. Preece, Douglas fir, (PM) (1); **Victoria**, 21-VI-34, G. A. Hardy, apple tree, (PM) (1); Hosts: numerous deciduous spp. (Barr 1971).

Chrysobothris nixa Horn: **Millstream**, 1-VIII-25, G. A. Hardy, in a gallery in *Thuja plicata*, (PM) (2); Hosts: *Libocedrus decurrens*, *Thuja plicata* and *Juniperus occidentalis* (Barr 1971).

Chrysobothris caurina Horn: **Cowichan L.**, 20-VII-40, K. Graham, *Pinus contorta*, (PF) (1); **Wellington**, anonymous (1906); Hosts: *Pinus* spp., *Abies concolor*, *Larix occidentalis*, *Pseudotsuga menziesii* and *Tsuga mertensiana* (Barr 1971).

Subfamily Acmaeoderinae
Tribe Acmaeoderini

Chrysophana placida LeC.: **Victoria**, 17-VI-69, B. Cousins, (UV) (1); 5-VI-67, R. Morley, (UV) (1); 10-VI-34, G. A. Hardy, *Abies grandis*, (PM) (4); **Errington**, 6-III-39, 24-VII-44, 9-VI-38, 2-VII-49, G. H. Larnder, (PM) (1); **Duncan**, 31-III-25, 16-III-18, A. W. Hanham, (PM) (1); Nanaimo, Holland (1888); Hosts: *Pinus* spp., *Abies* spp., *Pseudotsuga menziesii* and *Thuja plicata* (Barr 1971).

Subfamily Agrilinae
Tribe Agrilini

Agrilus politus (Say): **Victoria**, 5 to 20-V-26, G. A. Hardy, willow, (PM) (11); **Wellington**, anonymous (1906); Hosts: *Salix* spp. and *Acer* spp. (Barr 1971).

This list increases to 23, the known number of species of Buprestidae on Southern Vancouver Island. The collecting data indicate that buprestids are most common during the summer. This agrees with the observations of Hardy (1927, 1942).

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REFERENCES

Anonymous. 1906. The British Columbia list. Coleoptera. Family Buprestidae. Bull. B.C. Ent. Soc. 2:4.

Barr, W. F. 1971. Family Buprestidae. In Beetles of the Pacific Northwest, Part V, by M. H. Hatch. Univ. of Wash. Publ. Biol. 16. p. 662.

Cannings, R. A. and K. M. Stuart, 1977. The Dragonflies of British Columbia. B.C. Prov. Mus. Handbook no. 35; p. 256.

Evans, D. 1957. A revision of the genus **Poecilonota** in America north of Mexico (Coleoptera: Buprestidae). Ann. Ent. Soc. Am. 50:21-37.

Hardy, G. A. 1927. Buprestidae of Vancouver Island. Prov. B.C. Mus. Nat. Hist. for 1926: C32-C34.

________. 1942. Notes on some wood-boring beetles of Saanich Vancouver Island, B.C. (Coleoptera, Cerambycidae, Buprestidae) Proc. Ent. Soc. B.C. 39:9-13.

Hatch. M. H. 1953. The Beetles of the Pacific Northwest, Part I, Introduction and Adephaga. Univ. Wash. Publ. Biol. 16. p. 348.

Holland, W. J. 1888. Captures made while travelling from Winnipeg to Victoria, B.C. Can. Ent. 20:89-92.

LeConte, J. L. 1869. List of Coleoptera collected in Vancouver's Island by Henry and Joseph Matthews, with descriptions of some new species. Ann. Mag. Nat. Hist. Ser. 4. 6:369-385.

Walker, F. 1866. List of Coleoptera. In Lord's Naturalist in Vancouver Island and British Columbia Vol. 2: 309-334.

EUTROMULA PARIANA (CLERCK) (LEPIDOPTERA: CHOREUTIDAE), THE CORRECT NAME OF THE APPLE-AND-THORN SKELETONIZER

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ABSTRACT

Nomenclatural problems are noted which make *Eutromula pariana* (Clerck) the correct name of the apple-and-thorn skeletonizer. Previously used generic names are distinct genera (*Anthophila* Haworth and *Hemerophila* Hübner, [1817]), synonyms (*Simaethis* Leach), or unavailable names ("*Hemerophila*" Hübner, 1806). The species is now placed in the family Choreutidae (Sesioidea) which has been separated from Glyphipterigidae (Copromorphoidea).

The apple-and-thorn skeletonizer, *Eutromula pariana* (Clerck), is an occasional pest of apple trees, introduced from Europe this century. It is now firmly established in apple growing areas of the northeastern United States and southeastern Canada, and in British Columbia, going south to Oregon, Idaho, and Colorado. The specific name of the species has been combined with several generic names in the past, mostly *Anthophila*, *Simaethis*, and *Hemerophila*. The latter generic association was most recently affirmed by Danilevsky and Kuznetsov (1973) and noted by Doganlar (1977).

In a forthcoming revision of the North American Choreutidae (Heppner, in prep.), the name used for the species will be *Eutromula pariana*, following the combination used in a recent British checklist of Lepidoptera (Bradley, 1972). Danilevsky and Kuznetsov (1973), unfortunately, used an 1806 Hübner generic name that is now unavailable for use due to the rejection of Hübner's 1806 paper by the International Commission on Zoological Nomenclature (Opinion 97, 1926). The next available generic name is *Eutromula* Frölich, 1828, with *E. pariana* as its type-species. The available and valid *Hemerophila* Hübner, [1817] (not Hübner, 1806), refers to a Neotropical genus. *Simaethis* Leach, 1815 is a junior synonym of *Anthophila* Haworth, [1811], which refers to a genus distinct from *Eutromula*.

Although there are dark and light forms of *E. pariana*, both in the Nearctic and the Palearctic, Doganlar (1977) correctly noted that only one species is involved. A recent paper has noted the reasons for the separation of glyphipterigid moths into two families. Glyphipterigidae[1] and Choreutidae (Heppner, 1977). The two families actually are unrelated and belong in different superfamilies based upon morphological and biological features, thus, Copromorphoidea and Sesioidea, respectively, with Choreutidae being relatively closely related to the specialized Sesiidae.

1. Glyphipterigidae is based on the original spelling of **Glyphipterix** as required by the International Code of Zoological Nomenclature, rather than the emendation **Glyphipteryx** (Glyphipterygidae).

REFERENCES

Bradley, J. D. 1972. (Microlepidoptera parts). Part 2: Lepidoptera [in part]. In, Kloet and Hincks, A check list of British insects. Second Edition (revised). Royal Ent. Soc. Lond., London. 153 pp.

Danilevsky, A. S., and V. I. Kuznetsov. 1973. (A review of the glyphipterygid moths of the genus **Hemerophila** Hb. (Lepidoptera, Glyphipterygidae) of the fauna of the USSR.). Tr. Vsesoyuz. Ent. Obshch. 56:8-17. [in Russian].

Doganlar, M. 1977. The systematic position of the apple-and-thorn skeletonizer. J. Ent. Soc. Br. Columbia 74:26.

Heppner, J. B. 1977. The status of the Glyphipterigidae and a reassessment of relationships in yponomeutoid families and ditrysian superfamilies. J. Lepid. Soc. 31:124-134.

Heppner, J. B. (in prep.). Sesioidea. Choreutidae. In, Dominick, et al, The moths of America north of Mexico. Fasc. 8.4. Classey, London. (approx. 100 pp., 4 pls.).

Opinion 97. 1926. Did Hübner's Tentamen, 1806, create monotypic genera? Smithson. Misc. Coll. 73:19-30.

LARVAL TAXONOMY AND DISTRIBUTION OF *GERRIS PINGREENSIS* AND *G. INCOGNITUS* (HEMIPTERA: GERRIDAE) IN BRITISH COLUMBIA

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ABSTRACT

Diagnostic morphological characters are given for the five larval instars of *Gerris pingreensis* and *Gerris incognitus*. The geographic ranges of the two species are compared and discussed.

INTRODUCTION

Waterstriders (*Gerris*) are common inhabitants of British Columbia's inland waters. Ease of observation and the common occurrence of multispecies assemblages make these insects attractive subjects for comparative ecological study. A knowledge of species characteristics and natural history are necessary prerequisites for such work.

Scudder (1971) provided keys and descriptions for the adults of British Columbia gerrids and Scudder and Jamieson (1972) produced an identification guide for the larvae of seven species. At the time of these publications it was not possible to separate the first three instars of *Gerris pingreensis* D&H and *Gerris incognitus* D&H. Furthermore, the characteristics noted for separation of fourth and fifth instars of these two species are inefficient because of a typographical error missed in the proof.

In this paper we provide diagnostic descriptions for all larval instars of both species and compare the geographic ranges of these two species in British Columbia. Areas of sympatry and allopatry are noted.

METHODS AND MATERIALS

During May 1976 and 1977 we established laboratory cultures of *G. pingeensis* and *G. incognitus*. Adult *G. pingreensis* were collected from Westwick Lake in the Cariboo region while *G. incognitus* were obtained from small ponds in the University of British Columbia Endowment Lands. All five larval instars of both species were subsequently reared from eggs laid by isolated adults. Details of the rearing methods are given by Scudder and Jamieson (1972). Specimens of each larval instar were preserved in 70% ethanol 1 or 2 days after molting. Instar descriptions are based upon study of these laboratory-reared specimens. We have also checked the descriptions against field material collected on the lower mainland and in the central interior from locations where only one of the species is known to occur.

RESULTS AND DISCUSSION

A. Larval Taxonomy

The keys and descriptions provided by Scudder and Jamieson (1972) afford easy separation of *G. pingeensis* and *G. incognitus*

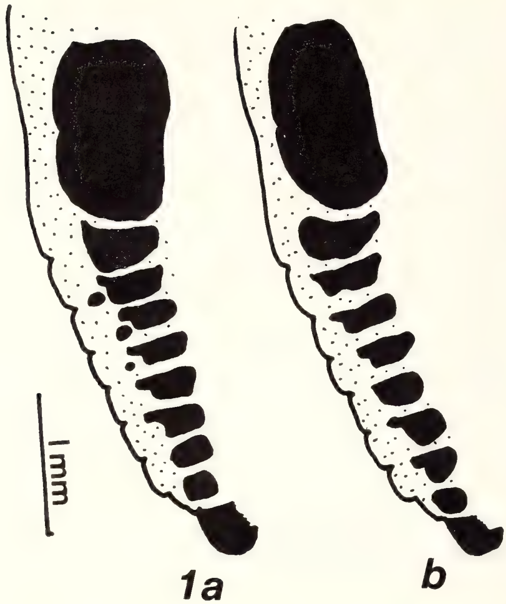

Figure 1. First Instar (a) **G. pingreensis** (b) **G. incognitus.**

from other gerrid species in the province. The descriptions that follow can be used to separate the five instars of these two species. Diagnostic measurements provided by Scudder and Jamieson (1972) are additionally helpful for identifying the fourth and fifth instars.

First and Second Instars

G. pingreensis: (Fig. 1a) with small but distinct sclerotized spots at the postero-lateral corners of at least the 2nd and 3rd abdominal terga.

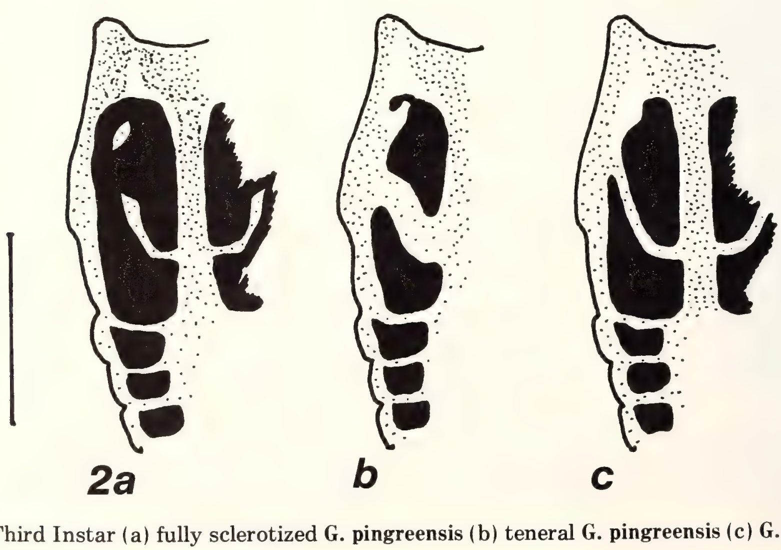

Figure 2. Third Instar (a) fully sclerotized **G. pingreensis** (b) teneral **G. pingreensis** (c) **G. incognitus.**

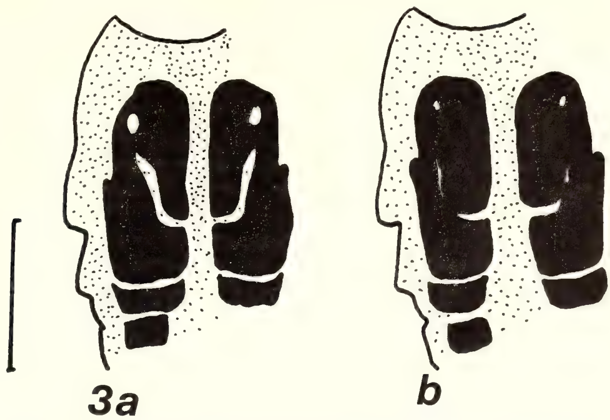

Figure 3. Fourth Instar (a) **G. pingreensis** (b) **G. incognitus.**

G. incognitus: (Fig. 1b) without such markings or with only an indistinct spot near the 2nd abdominal tergum.

Third Instar

G. pingreensis:

fully sclerotized specimens (Fig. 2a) arrow-shaped mark on mesonotum not extending to the antero-lateral corner of the notum; distinct light spot in the antero-lateral corner of the mesonotum.

teneral specimens (Fig. 2b) sides of mesonotal arrow with broad light bands and expanded light area in the antero-lateral corner.

G. incognitus: (Fig. 2c) sides of arrow-shaped mark on mesonotum extending to the antero-lateral corner as a narrow light band; distinct light spot never delimited within the mesonotum.

Fourth and Fifth Instars

G. pingreensis: (Figs. 3a and 4a) with distinct arrow-shaped mark on mesonotum; isolated light spot in antero-lateral corner of mesonotum always present in 4th instar and usually present in 5th instar.

G. incognitus: (Figs. 3b and 4b) arrow-shaped mark on mesonotum poorly defined; lateral portion of arrow's head not present or ex-

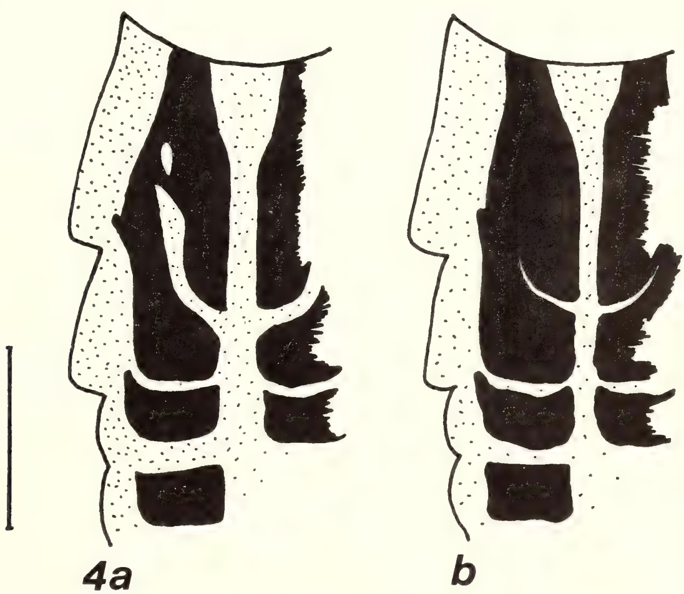

Figure 4. Fifth Instar (a) **G. pingreensis** (b) **G. incognitus.**

tending to the antero-lateral corner of the mesonotum only as a very thin line which is barely distinguishable from the surrounding sclerotization; 4th instar occasionally with isolated light spot at the antero-lateral corner of the mesonotum, such markings never present in 5th instar.

B. Distribution

Locality records of these two species in British Columbia are plotted in Figure 5. The records are taken from Scudder (1977) and from additional collections in the Chilcotin region during the Spring and Summer of 1977.

The ranges of these two species are somewhat complementary in British Columbia. *Gerris incognitus* is the dominant species of the pair in the southern half of the province. However it is not generally successful in the parkland of the central interior even though clear access seems possible from both east and west. *Gerris pingreensis* is the only species of the pair to be recorded from the northern interior and occurs without *G. incognitus* on the interior Chilcotin Plateau.

Although these two species are generally allopatric in British Columbia, a broad zone of overlap occurs in the central interior. This area is one of the main suture zones in the province where species from the prairies have establish-

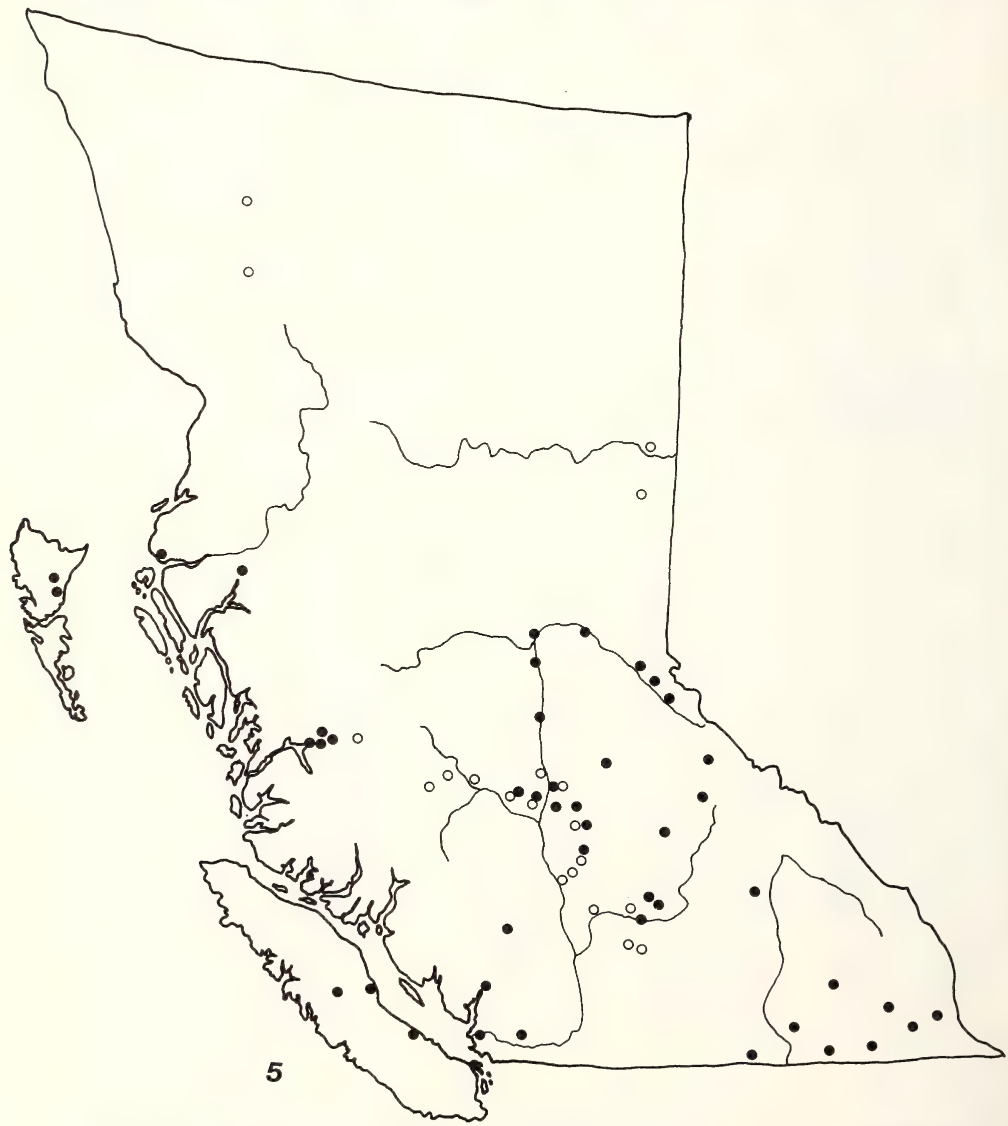

Figure 5. Distribution of **G. pingreensis** (o) and **G. incognitus** (●) in British Columbia.

ed contact with Cordilleran species. Remington (1968) points out that significant biological interactions often occur between similar species in such suture zones.

The fact that *G. pingreensis* and *G. incognitus* co-occur over such a broad area in the central interior suggests either that these species are not experiencing significant interspecific competition despite their pronounced similarity or that competitive advantages are shifting over space or fluctuating in time. We shall discuss these possibilities in more detail elsewhere.

ACKNOWLEDGEMENTS

This research was supported by a grant to G. G. E. Scudder from the National Research Council of Canada. We thank D. H. Spence for her meticulous care of young waterstriders.

LITERATURE CITED

Remington, C. L. 1968. Suture zones of hybrid interaction between recently joined biotas. Evol. Biol. 2: 321-428.

Scudder, G. G. E. 1977. An annotated checklist of the aquatic and semiaquatic Hemiptera (Insecta) of British Columbia. Syesis 10: 31-38.

Scudder, G. G. E. 1971. The Gerridae (Hemiptera) of British Columbia. J. Entomol. Soc. Brit. Columbia 68: 3-10.

Scudder, G. G. E. and G. S. Jamieson. 1972. The immature stages of Gerris (Hemiptera) in British Columbia. J. Entomol. Soc. Brit. Columbia 69: 72-79.

THE APHIDS (HOMOPTERA:APHIDIDAE) OF BRITISH COLUMBIA 5. NAME CHANGES[1]

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ABSTRACT

Name changes in accordance with current usage in aphid taxonomy are listed.

INTRODUCTION

An approach to a stable nomenclature for aphids became possible with the recent publication of a "Survey of the World's Aphids" (Eastop and Hille Ris Lambers 1976). We decided to adopt that work as a standard for all our aphid names. This has necessitated changing 72 names used in our previous lists (Forbes, Frazer and MacCarthy 1973; Forbes, Frazer and Chan 1974; Forbes and Chan 1976). All of these changes are listed here. They are arranged alphabetically by genus and species of the names used previously.

[1]Contribution No. 416, Research Station, 6660 N.W. Marine Drive, Vancouver, British Columbia, V6T 1X2.

LIST OF NAME CHANGES

Previous Name	**Current Name**
Acyrthosiphon dirhodum (Walker)	*Metopolophium dirhodum* (Walker)
Acyrthosiphon pisum spartii (Koch)	*Acyrthosiphon pisum* (Harris)
Allaphis verrucosa (Gillette)	*Thripsaphis verrucosa* Gillette
Aphis corniella Hille Ris Lambers	*Aphis salicariae* Koch
Aphis sambucifoliae Fitch	*Aphis sambuci* Linnaeus
Asiphum rosettei Maxson	*Asiphum tremulae* (Linnaeus)
Aspidaphis longicauda Richards	*Eoessigia longicauda* (Richards)
Aulacorthum clavicornis Richards	*Wahlgreniella nervata* (Gillette)
Aulacorthum dorsatum Richards	*Sitobion dorsatum* (Richards)
Aulacorthum scabrosum Richards	*Aulacorthum capilanoense* Robinson
Bipersona torticauda Gillette	*Bipersona ochrocentri* (Cockerell)
Brachycolus atriplicis (Linnaeus)	*Hayhurstia atriplicis* (Linnaeus)
Cavariella umbellatarum (Koch)	*Cavariella aegopodii* (Scopoli)
Cepegillettea betulaefoliae Granovsky	*Calaphis betulaefoliae* (Granovsky)
Chaitophorus delicata Patch	*Chaitophorus stevensis* Sanborn
Chaitophorus neglectus Hottes & Frison	*Chaitophorus populifolii neglectus* Hottes & Frison

Cinara abieticola Cholodkovsky	*Cinara confinis* (Koch)
Colopha ulmisacculi Patch	*Tetraneura ulmi* (Linnaeus)
Dactynotus ambrosiae (Thomas)	*Uroleucon ambrosiae* (Thomas)
Dactynotus cirsii (Linnaeus)	*Uroleucon cirsii* (Linnaeus)
Dactynotus erigeronensis (Thomas)	*Uroleucon erigeronensis* (Thomas)
Dactynotus nigrotuberculatus Olive	*Uroleucon nigrotuberculatum* (Olive)
Dactynotus pseudambrosiae Olive	*Uroleucon pseudambrosiae* (Olive)
Dactynotus russellae Hille Ris Lambers	*Uroleucon russellae* (Hille Ris Lambers)
Dactynotus sonchi (Linnaeus)	*Uroleucon sonchi* (Linnaeus)
Dactynotus taraxaci (Kaltenbach)	*Uroleucon taraxaci* (Kaltenbach)
Euschizaphis palustris (Theobald)	*Schizaphis palustris* (Theobald)
Holcaphis frequens (Walker)	*Diuraphis frequens* (Walker)
Holcaphis nodulus Richards	*Diuraphis nodulus* (Richards)
Hyadaphis erysimi (Kaltenbach)	*Lipaphis erysimi* (Kaltenbach)
Kakimia canadensis Robinson	*Delphiniobium canadense* (Robinson)
Kakimia essigi (Gillette & Palmer)	*Kakimia aquilegiae* (Essig)
Kakimia robinsoni Richards	*Kakimia wahinkae* (Hottes)
Macrosiphum avenae (Fabricius)	*Sitobion avenae* (Fabricius)
Macrosiphum coweni (Hunter)	*Obtusicauda artemisiae* (Cowen ex Gillette & Baker)
Macrosiphum fragariae (Walker)	*Sitobion fragariae* (Walker)
Macrosiphum manitobensis Robinson	*Sitobion manitobense* (Robinson)
Macrosiphum nigromaculosum MacDougall	*Eomacrosiphon nigromaculosum* (MacDougall)
Macrosiphum ptericolens Patch	*Sitobion ptericolens* (Patch)
Macrosiphum rhamni Clarke	*Sitobion rhamni* (Clarke)
Macrosiphum salicicornii Richards	*Sitobion salicicornii* (Richards)
Macrosiphum yagasogae (Hottes)	*Sitobion insulare yagasogae* (Hottes)
Masonaphis crystleae (Smith & Knowlton)	*Illinoia crystleae* (Smith & Knowlton)
Masonaphis davidsoni (Mason)	*Illinoia davidsoni* (Mason)
Masonaphis lambersi MacGillivray	*Illinoia lambersi* (MacGillivray)
Masonaphis magna Hille Ris Lambers	*Illinoia magna* (Hille Ris Lambers)
Masonaphis maxima (Mason)	*Illinoia maxima* (Mason)
Masonaphis morrisoni (Swain)	*Illinoia morrisoni* (Swain)
Masonaphis patriciae Robinson	*Illinoia patriciae* (Robinson)
Masonaphis pseudomorrisoni MacGillivray	*Illinoia morrisoni* (Swain)
Masonaphis richardsi MacGillivray	*Illinoia richardsi* (MacGillivray)
Masonaphis spiraeae MacGillivray	*Illinoia spiraeae* (MacGillivray)
Masonaphis spiraecola (Patch)	*Illinoia spiraecola* (Patch)
Masonaphis wahnaga Hottes	*Illinoia wahnaga* (Hottes)
Neoceruraphis viburnicola (Gillette)	*Ceruraphis viburnicola* (Gillette)
Parathecabius gravicornis (Patch)	*Thecabius gravicornis* (Patch)
Parathecabius populimonilis (Riley)	*Thecabius populimonilis* (Riley)
Prociphilus alnifoliae alnifoliae (Williams)	*Prociphilus alnifoliae* (Williams)
Pterocomma bicolor bicolor (Oestlund)	*Pterocomma bicolor* (Oestlund)
Rhopalosiphum fitchii (Sanderson)	*Rhopalosiphum insertum* (Walker)
Roepkea bakeri (Cowen)	*Nearctaphis bakeri* (Cowen)
Roepkea crataegifoliae (Fitch)	*Nearctaphis crataegifoliae* (Fitch)
Roepkea sclerosa Richards	*Nearctaphis sclerosa* (Richards)
Roepkea sensoriata (Gillette & Bragg)	*Nearctaphis sensoriata* (Gillette & Bragg)
Roepkea yohoensis (Bradley)	*Nearctaphis yohoensis* Bradley
Sipha kurdjumovi Mordvilko	*Sipha elegans* del Guercio
Sitomyzus columbiae Richards	*Utamphorophora humboldti* (Essig)
Sitomyzus humboldti (Essig)	*Utamphorophora humboldti* (Essig)
Stagona xylostei (de Geer)	*Prociphilus xylostei* (de Geer)
Thelaxes albipes Richards	*Thelaxes californica* (Davidson)
Trichocallis cyperi (Walker)	*Thripsaphis cyperi* (Walker)
Tuberculoides annulatus (Hartig)	*Tuberculatus annulatus* (Hartig)

REFERENCES

Eastop, V. F., and D. Hille Ris Lambers. 1976. Survey of the world's aphids. Dr. W. Junk b.v., Publishers, The Hague.

Forbes, A. R., and Cho-Kai Chan. 1976. The aphids (Homoptera:Aphididae) of British Columbia. 4. Further additions and corrections. J. ent. Soc. Brit. Columbia 73:57-63.

Forbes, A. R., B. D. Frazer and Cho-Kai Chan. 1974. The aphids (Homoptera: Aphididae) of British Columbia. 3. Additions and corrections. J. ent. Soc. Brit. Columbia 71:43-49.

Forbes, A. R., B. D. Frazer and H. R. MacCarthy. 1973. The aphids (Homoptera: Aphididae) of British Columbia. 1. A basic taxonomic list. J. ent. Soc. Brit. Columbia 70:43-57.

THE APHIDS (HOMOPTERA: APHIDIDAE) OF BRITISH COLUMBIA 6. FURTHER ADDITIONS[1]

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ABSTRACT

Twenty-four species of aphids and new host records are added to the taxonomic list of the aphids of British Columbia.

INTRODUCTION

Three previous lists of the aphids of British Columbia (Forbes, Frazer and MacCarthy 1973; Forbes, Fraser and Chan 1974; Forbes and Chan 1976) recorded 285 species, but with the deletion of 7 synonyms[2] (Eastop and Hille Ris Lambers 1976) the number becomes 278. This includes aphids collected from 421 hosts[3] or in traps and comprises 792 aphid-host plant associations[3].

The present list adds 24 species of aphids (indicated with an asterisk in the list) and 172 aphid-host plant associations to the previous lists. Ninety-three of the new aphid-host plant associations are plant species not in the previous lists. The additions bring the number of known aphid species in British Columbia to 302. Aphids have now been collected from 514 different host plants and the total number of aphid-host plant associations is 964.

As in the previous lists, the aphids are arranged alphabetically by species. All names are in accordance with Eastop and Hille Ris Lambers (1976). The location of each collection site can be determined from Table 1 or from tables of localities in the previous paper. The reference points are the same as those shown on the map which accompanies the basic list.

[1]Contribution No. 417, Research Station, 6660 N.W. Marine Drive, Vancouver, British Columbia, V6T 1X2.

[2]*Aulacorthum clavicornis* Richards,
Aulacorthum scabrosum Richards,
Cavariella umbellatarum (Koch),
Masonaphis pseudomorrisoni MacGillivray,
Rhopalosiphum fitchii (Sanderson),
Sitomyzus columbiae Richards,
Thelaxes albipes Richards.

[3]*Quercus borealis* and *Philadelphus lewisii* var. *gordonianus* of earlier lists being deleted as synonyms, based on Hortus Third.

TABLE 1. Localities where aphids were collected, with airline distances from reference points.

Locality	Reference Point	Dir.	Distance km	mi
Botanie Valley	Kamloops	SW	94	59
Colwood	Victoria	W	16	10
Harrison Lake	Vancouver	NE	114	71
Naramata	Kelowna	S	32	20
Peachland	Kelowna	SW	22	14
Port Coquitlam	Vancouver	E	37	23
Port Washington	Victoria	N	45	28
Silver Lake	Kelowna	W	53	33
Tulameen	Kelowna	SW	102	64
White Rock	Vancouver	SE	37	23
Yarrow	Vancouver	SE	92	58

LIST OF SPECIES

*ADIANTI (Oestlund), SITOBION
Athyrium filix-femina: Vancouver, May 2/58.
Polystichum munitum: North Vancouver, May 17/73; Vancouver, Apr 27/63, May 2/58, May 19/58; Vancouver (UBC), Jan 23/76, Feb 17/76, Mar 29/74, Apr 22/74, Apr 30/75, May 21/74, May 23/75.

*AFFINIS (Kaltenbach), THECABIUS
Ranunculus occidentalis: Vancouver, Dec 15/76, Dec 31/76.

AGATHONICA Hottes, AMPHOROPHORA
Rubus idaeus: Abbotsford, Aug 2/74; North Vancouver, Jun 18/74; Vancouver, Jun 22/75; Yarrow, Aug 2/74.

ALNI (de Geer), PTEROCALLIS
Alnus rubra: Vancouver (UBC), May 12/76, May 18/76.
Rosa sp: Pemberton, Jul 16/76.

ALNIFOLIAE (Williams), PROCIPHILUS
Amelanchier alnifolia: Peachland, May 21/76.

AQUILEGIAE (Essig), KAKIMIA
Aquilegia alpina: Vancouver (UBC), Jun 28/76.
Aquilegia formosa: Vancouver (UBC), Aug 13/76.

ASCALONICUS Doncaster, MYZUS
Anemone pulsatilla: Vancouver (UBC), Aug 13/76.
Bellis perennis: Vancouver (UBC), Feb 8/77, Jul 14/76.
Cerastium fontanum ssp triviale: Vancouver (UBC), Dec 15/76.
Claytonia sibirica var sibirica: Vancouver (UBC), Feb 8/77.
Meconopsis betonicifolia: Vancouver (UBC), Jun 28/76.
Myosotis arvensis: Vancouver, May 17/76.
Phlox paniculata: Vancouver (UBC), May 1/58.
Ranunculus occidentalis: Vancouver, Dec 31/76.
Stellaria media: Vancouver (UBC), Jul 10/75.
Viburnum x *bodnantense:* Vancouver (UBC), May 23/76.

*AUDENI MacDougall, MACROSIPHUM
Nuphar lutea ssp *polysepala:* Merritt, /24. (MacDougall 1926).

BERBERIDIS (Kaltenbach), LIOSOMAPHIS
Berberis verruculosa: Vancouver (UBC), May 20/76.

BICOLOR (Oestlund), PTEROCOMMA
Populus nigra 'Italica': Vancouver (UBC), May 3/74.

*BISENSORIATUM MacDougall, MACROSIPHUM
Ribes lacustre: Boundary Bay, Jul /24, (MacDougall 1926), Aug /24, (MacDougall 1926).

BRASSICAE (Linnaeus), BREVICORYNE
Brassica pekinensis: Richmond, Aug 20/76.
Brassica rapa var lorifolia: Richmond, Aug 20/76.

CALIFORNICA (Davidson), THELAXES
Quercus garryana: Colwood, May 9/76.

CALIFORNICUM (Clarke), MACROSIPHUM
Salix scouleriana: Vancouver (UBC), Jun 13/75.

*CALLIPTERUS (Hartig), CALLIPTERINELLA
Betula pendula 'Dalecarlica': Vancouver, May 26/76.

CAPILANOENSE Robinson, AULACORTHUM
Polystichum munitum: Vancouver, May 2/58.
Rubus spectabilis: Vancouver (UBC), Apr 30/76, May 14/76, Jul 14/76.

CARAGANAE (Cholodkovsky), ACYRTHOSIPHON
Caragana arborescens: Vancouver (UBC), Oct 6/75.
Colutea melanocalyx: Vancouver (UBC), Aug 4/76.

CARDUI (Linnaeus), BRACHYCAUDUS
Cirsium arvense: Summerland, Jul 3/76.
Rhus sp: Vancouver (UBC), Jun 1/76.

*CARICIS (Glendenning), SITOBION
Carex sp: Agassiz, Aug /26, (Glendenning 1926).

CERASI (Fabricius), MYZUS
Galium mollugo: Vancouver, Jul 21/76.
Liriodendron tulipifera: Vancouver (UBC), Oct. 6/75.
Prunus emarginata: Vancouver (UBC), Jun 7/75.
Prunus 'Royal Anne': Vancouver (UBC), Sep 23/76.
Prunus serrulata 'Kwanzan': Vancouver (UBC), Jun 24/75.

CERASIFOLIAE (Fitch), RHOPALOSIPHUM
Prunus virginiana: Lumby, Jul 14/76; Summerland, Jun 14/76.

CIRCUMFLEXUM (Buckton), AULACORTHUM
Papaver orientale: Vancouver, Jul 20/58.

CIRSII (Linnaeus), UROLEUCON
Cirsium arvense: Summerland, Jul 3/76.

*CITRICOLA van der Goot, APHIS
Calycanthus fertilis: Vancouver (UBC), Jul 20/76.
Stranvaesia davidiana: Vancouver (UBC), Jul 30/76.

COLUMBIAE Richards, TUBERCULATUS
Quercus garryana: Colwood, May 9/76.

CORNI (Fabricius), ANOECIA
Cornus alba 'Sibirica': Vancouver (UBC), Sep 22/75.

Cornus nuttallii: Vancouver (UBC), Oct 6/75.
Cornus purpusii: Vancouver (UBC), Sep 22/75, Sep 25/75.
Cornus sanguinea: Vancouver (UBC), Oct 6/75.
Cornus sericea: Peachland, May 21/75; Vancouver (UBC), Nov 7/75.

COWENI (Cockerell), TAMALIA
Arctostaphylos uva-ursi: Vancouver (UBC), Jun 24/76, Jul 18/76, Aug 25/76, Sept 9/76.

*CRACCAE Linnaeus, APHIS
Moericke yellow pan water trap: Penticton, Jun 30/75.

CURVIPES (Patch), CINARA
Abies grandis: Vancouver (UBC), May 18/76.

DIRHODUM (Walker), METOPOLOPHIUM
Rosa sp: Pemberton, Jul 16/76.

DORSATUM (Richards), SITOBION
Gaultheria shallon: Vancouver (UBC), Jul 27/76.

EPILOBII Kaltenbach, APHIS
Epilobium ciliatum: Vancouver, May 25/76.

ERIOPHORI (Walker), CERURAPHIS
Viburnum opulus ssp *trilobum:* Vancouver (UBC), Oct 6/75.
Viburnum x *bodnantense:* Vancouver (UBC), Jun 1/76.

ERYSIMI (Kaltenbach), LIPAPHIS
Brassica rapa ssp *campestris:* Abbotsford, Jul 5/76; Vancouver, Jul 27/76.

EUPHORBIAE (Thomas), MACROSIPHUM
Balsamorhiza sagittata: Penticton, May 23/76.
Brassica rapa ssp *campestris:* Vancouver, Jul 27/76.
Callistephus chinensis: Vancouver, Jun 16/76.
Cornus sericea: Vancouver (UBC), Nov 7/75.
Daphne cneorum: Vancouver (UBC), May 19/76, May 25/76.
Daphne laureola: Vancouver (UBC), May 19/76, Jun 28/76.
Hibiscus rosa-sinensis: Vancouver (CDA), Aug 17/76.
Hieracium aurantiacum: Vancouver (UBC), Aug 23/76.
Hosta sieboldiana: Vancouver (UBC), Aug 16/76.
Incarvillea mairei var *grandiflora:* Vancouver (UBC), Jun 28/76.
Jacaranda acutifolia: Port Coquitlam, Aug 22/76.
Liriodendron tulipifera: Vancouver (UBC), Jul 22/75, Aug 9/76, Oct 6/75.
Myosotis arvensis: Vancouver, May 25/76.
Nothofagus antarctica: Vancouver (UBC), Jun 11/76.
Oemleria cerasiformis: Vancouver, Apr 27/73.
Photinia x *fraseri:* Vancouver (UBC), Jul 29/76.
Rubus spectabilis: Vancouver (UBC), May 14/76.
Solanum tuberosum: Quesnel, Jul 21/76.
Symphoricarpos albus: Vancouver, Jul 21/76.
Yucca filamentosa: Vancouver, Aug 15/74.

FABAE Scopoli APHIS
Arctostaphylos uva-ursi: Vancouver (UBC), Sep 9/76, Sep 23/75.
Beta vulgaris: Brentwood, Jul 5/59; Ladner, Aug 27/58.
Calendula officinalis: Vancouver, Aug 12/76.
Crocosmia x *crocosmiiflora:* Vancouver, Aug 12/76.
Ficus carica: Vancouver (UBC), Aug 14/75.
Galium mollugo: Vancouver, Jul 21/76.
Holodiscus discolor: Vancouver (UBC), Oct 3/75.
Hosta undulata: Vancouver, Aug 19/76.
Liriodendron tulipifera: Vancouver (UBC), Sep 11/75, Oct 6/75.
Lunaria annua: Vancouver, Aug 18/76.
Lysimachia punctata: Vancouver, Jul 21/76.
Phlox paniculata: Vancouver, Aug 12/76.
Physalis alkekengi: Vancouver, Aug 12/76.
Rhus sp: Vancouver (UBC), Jun 1/76.
Tropaeolum majus: Vancouver, Aug 18/76.
Viburnum opulus ssp *trilobum:* Vancouver (UBC), Oct 6/75.
Yucca filamentosa: Vancouver, Aug 1/74, Aug 10/74, Aug 15/74.

FAGI (Linnaeus), PHYLLAPHIS
Fagus sylvatica 'Atropunicea': Vancouver, Jun 1/76.

FARINOSA Gmelin, APHIS
Salix scouleriana: Vancouver (UBC), Jun 13/75.

FIMBRIATA Richards, FIMBRIAPHIS
Liriodendron tulipifera: Vancouver (UBC), Aug 9/76.

*FLAVA Mordvilko, CALAPHIS
Betula sp: Burnaby, Jul 14/63.

*FOENICULI (Passerini), HYADAPHIS
Lonicera ciliosa: Port Washington, Jun 8/76.

FORNACULA Hottes, CINARA
Picea sp: Richmond, Jul 4/76.

FRAGAEFOLII (Cockerell), CHAETOSIPHON
Rosa sp: Pemberton, Jul 16/76.

FRAGARIAE (Walker), SITOBION
Cortaderia selloana: Vancouver, Jul 21/76.
Rubus discolor: Vancouver (UBC), Jul 25/75.
Grass: Vancouver (UBC), Jun 22/76.

*FUSCICORNIS MacDougall, MACROSIPHUM
Epilobium angustifolium: Merritt, Jun 29/24, (MacDougall 1926); Vancouver, Aug 24/24, (MacDougall 1926).

GALEOPSIDIS (Kaltenbach), CRYPTOMYZUS
Ribes sativum: Quesnel, Jul 21/76.

GENTNERI (Mason), FIMBRIAPHIS
Amelanchier laevis: Vancouver (UBC), May 16/75, Oct 3/75.
Amelanchier ovalis: Vancouver (UBC), Jun 28/76, Oct. 10/75.
Crataegus monogyna: Vancouver, May 26/76.
Mespilus germanica: Vancouver (UBC), May 28/75.

HEDERAE Kaltenbach, APHIS
Hedera helix: Saanich, May 9/76; Vancouver (UBC), Apr 29/76.

HELIANTHI Monell, APHIS
Cornus sericea: Peachland, May 21/76.

HELICHRYSI (Kaltenbach), BRACHYCAUDUS
Chrysanthemum x *morifolium:* Vancouver, Jul 21/76.
Prunus cerasifera 'Atropurpurea': Vancouver (UBC), Jun 26/75.
Prunus domestica: Lumby, Jul 4/76; Pemberton, Jul 16/76; Summerland, Jun 10/76.

*HELVETICA Hille Ris Lambers, BETULAPHIS
Betula sp: Vancouver, Oct 3/60.

HIPPOPHAES (Walker), CAPITOPHORUS
Polygonum lapathifolium: Vancouver (UBC), Aug 18/75.

HUMBOLDTI (Essig), UTAMPHOROPHORA
Physocarpus capitatus: Silver Lake, Oct 21/75.
Physocarpus malvaceus: Vancouver (UBC), Nov 4/75.

HUMULI (Schrank), PHORODON
Prunus domestica: Lumby, Jul 4/76.

INSERTUM (Walker), RHOPALOSIPHUM
Chaenomeles japonica: Vancouver (UBC), Oct 6/75.
Liriodendron tulipifera: Vancouver (UBC), Oct 6/75.
Malus ioensis: Vancouver (UBC), Apr 27/76, May 4/76, Oct 7/75.
Mespilus germanica: Vancouver (UBC), May 28/75, Oct 6/75.

*JUNIPERI (de Geer), CINARA
Juniperus squamata 'Meyeri': Vancouver (UBC), Aug 4/76, Sep 22/75.

LAMBERSI (MacGillivray), ILLINOIA
Daboecia cantabrica: Vancouver (UBC), Sep 23/75.
Daboecia cantabrica 'Alba': Vancouver (UBC), Sep 23/75.
Daboecia cantabrica 'Atropurpurea': Vancouver (UBC), Jun 28/76.
Daboecia cantabrica 'Praegerae': Vancouver (UBC), Jun 28/76.
Rhododendron 'Elizabeth': Vancouver (UBC), Mar 29/76, Apr 26/76, Jun 16/76.
Rhododendron molle: Vancouver (UBC), Jun 30/76.

*LIRIODENDRI (Monell), ILLINOIA
Liriodendron tulipifera: Vancouver (UBC), Aug 9/76.

LONGICAUDA (Richards), EOESSIGIA
Spiraea douglasii: Vancouver (UBC), Jul 27/76, Nov 7/75.

MACROSIPHUM (Wilson), ACYRTHOSIPHON
Amelanchier laevis: Vancouver (UBC), Oct 3/75.

MILLEFOLII (de Geer), MACROSIPHONIELLA
Achillea millefolium: Vancouver (UBC), Sep 23/75.

MORRISONI (Swain), ILLINOIA
Chamaecyparis lawsoniana: Vancouver (UBC), Sep 19/75.
x*Cupressocyparis leylandii:* Vancouver (UBC), Jun 10/75, Aug 29/75.
Juniperus squamata 'Meyeri': Vancouver (UBC), Aug 4/76, Sept 22/75, Oct 3/75, Nov 4/75.

NASTURTII Kaltenbach, APHIS
Moericke yellow pan water trap: Naramata, Oct 14/75; Penticton, Oct 14/75.

NEPHRELEPIDIS Davis, IDIOPTERUS
Saintpaulia ionantha: Vancouver, Apr 22/76.

NERVATA (Gillette), WAHLGRENIELLA
Arbutus menziesii: Vancouver (UBC), Jan 20/76, Sep 23/76, Nov 12/75, Dec 30/75.
Hypericum patulum 'Hidcote': Vancouver (UBC), Jul 20/76.

NIGROMACULOSUM (MacDougall), EOMACROSIPHON
Rosa nutkana: Botanie Valley, Jun 28/24, (MacDougall 1926); Merritt, Jul 10/24, (MacDougall 1926).

NODULUS (Richards), DIURAPHIS
Moericke yellow pan water trap: Naramata, Oct 14/75.

NYMPHAEAE (Linnaeus), RHOPALOSIPHUM
Chaenomeles japonica: Vancouver (UBC), Oct 6/75.

*OCCIDENTALIS Hille Ris Lambers & Hottes, BOERNERINA
Moericke yellow pan water trap: Penticton, Jun 23/75.

ORNATUS Laing, MYZUS
Alstroemeria aurantiaca: Vancouver (UBC), Sep 20/76.
Arabis caucasica: Vancouver (UBC), Jun 28/76.
Begonia cucullata var hookeri: Vancouver, May 3/76.
Galium mollugo: Vancouver, Jul 21/76.
Gardenia jasminoides: Vancouver, Jan 3/77.
Halesia carolina: Vancouver (UBC), Jul 10/75.
Hypericum patulum 'Hidcote': Vancouver

(UBC), Jul 20/76.
Impatiens sp: Vancouver, Jun 2/76.
Myosotis arvensis: Vancouver, May 17/76, May 25/76.
Nepeta cataria: Vancouver (UBC), Jun 28/76.
Philodendron hastatum: Vancouver, Feb 22/76.
Rosmarinus officinalis: Vancouver, Feb 9/77.
Thymus pseudolanuginosus: Vancouver (UBC), Sep 20/76.
Viburnum x *bodnantense:* Vancouver (UBC), Jun 1/76.

OSMARONIAE (Wilson), MACROSIPHUM
Oemleria cerasiformis: Vancouver (UBC), Apr 22/76, May 30/75.

*PAPILLATA Theobald, JACKSONIA
Grass: Vancouver, Dec 15/76.

PARVIFLORI Hill, AMPHOROPHORA
Rubus ursinus: North Vancouver, Jun 18/74.

PATRICIAE (Robinson), ILLINOIA
Tsuga heterophylla: Vancouver (UBC), Jul 23/75, Aug 15/75.

PERSICAE (Sulzer), MYZUS
Aralia elata: Vancouver (UBC), Aug 25/76.
Beta vulgaris: Brentwood, Jul 5/59; Ladner, Aug 27/58.
Buddleia davidii: Vancouver (UBC), May 19/76.
Capsicum sp: Vancouver, Feb 22/76.
Epidendrum ibaguense: Vancouver (UBC), Sep 22/76.
Hibiscus rosa-sinensis: Vancouver (CDA), Aug 17/76, Sep 3/76.
Meconopsis paniculata: Vancouver (UBC), Jun 28/76.
Physalis alkekengi: Vancouver, Aug 12/76.
Silene alba ssp *alba:* Vancouver (UBC), Jun 3/76.
Trientalis latifolia: Vancouver (UBC), Jun 2/76.
Yucca filamentosa: Vancouver, Aug 15/74.

PISUM (Harris), ACYRTHOSIPHON
Medicago sativa: Summerland, Jul 3/76.
Melilotus alba: Vancouver (UBC), Aug 19/76.
Pisum sativum var *arvense:* Sumas, Jun 26/59; Vancouver, Jul 13/64.
Vicia sativa var *angustifolia:* Saanich, May 9/76.

PLANTAGINEA (Passerini), DYSAPHIS
Malus ioensis: Vancouver (UBC), Apr 27/76, May 4/76, Oct 7/75.

*POLEMONII (Gillette & Palmer), KAKIMIA
Moericke yellow pan water trap: Summerland, Jun 30/75.

POMI de Geer, APHIS
Crataegus monogyna: Vancouver, May 26/76.
Photinia x *fraseri:* Vancouver (UBC), Jul 29/76.

*POPULICAULIS Fitch, PEMPHIGUS
Populus trichocarpa: Vancouver (UBC), May 27/76, Jun 7/76, Jul 5/76; White Rock, May 22/76.

POPULIVENAE Fitch, PEMPHIGUS
Populus trichocarpa: Peachland, May 21/76; Vancouver (UBC), Jun 7/76.

PRUNI (Geoffroy), HYALOPTERUS
Cortaderia selloana: Vancouver, Jul 21/76.
Liriodendron tulipifera: Vancouver (UBC), Aug 9/76.
Prunus domestica: Lumby, Jul 4/76; Pemberton, Jul 16/76; Summerland, Jun 10/76, Jul 3/76.

PRUNI Wilson & Davis, ASIPHONAPHIS
Prunus virginiana: Summerland, Jun 14/76.

*PTERIDIS (Wilson), SITOBION
Pteridium aquilinum: Vancouver (UBC), Jul 23/74.

PUNCTIPENNIS (Zetterstedt), EUCERAPHIS
Betula pendula 'Dalecarlica': Vancouver, May 26/76.
Betula sp: Burnaby, Jul 14/63.

*PYRIFOLIAE MacDougall, MACROSIPHUM
Sorbus sitchensis ssp *grayi:* Merritt, May 27/74, (MacDougall 1926); Tulameen, Jun 15/24, (MacDougall 1926).

*RARA Mordvilko, TRAMA
Moericke yellow pan water trap: Vancouver (UBC), Aug 1/76.

RHAMNI (Clarke), SITOBION
Rhamnus purshiana: Vancouver (UBC), Apr 7/75, Oct 3/75.

RIEHMI (Borner), THERIOAPHIS
Melilotus alba: Vancouver (UBC), Aug 19/76.

ROBINIAE (Gillette), APPENDISETA
Sophora japonica: Vancouver (UBC), Aug 4/76.

ROSAE (Linnaeus), MACROSIPHUM
Ilex aquifolium: Richmond, Jul 4/76.
Rosa sp: North Vancouver, Jun 18/74.

RUBITOXICA Knowlton, AMPHOROPHORA
Rubus ursinus: Vancouver (UBC), Jul 26/76.

RUMEXICOLENS (Patch), BRACHYCAUDUS
Rumex acetosella: Vancouver (UBC), May 27/76.

SALICARIAE Koch, APHIS
Cornus alba 'Argenteo-marginata': Vancouver (UBC), Jun 3/75.
Cornus mas: Vancouver (UBC), Sep 22/75.
Cornus nuttallii: Vancouver (UBC), Oct 6/75.
Cornus purpusii: Vancouver (UBC), Sep 22/75, Sep 25/75.
Cornus sanguinea: Vancouver (UBC), Oct 6/75, Nov 4/75.

SEDI Kaltenbach, APHIS
Sedum sp: Vancouver, Jul 7/76.

*SITCHENSIS Glendenning, EUCERAPHIS

Alnus viridis ssp *sinuata:* Harrison Lake, May /26, (Glendenning 1926).

SOLANI (Kaltenbach), AULACORTHUM

Aeschynanthus radicans: Vancouver (CDA), May 6/76.

Androsace sarmentosa: Vancouver (UBC), May 6/76.

Aquilegia sp: Vancouver, May 11/76.

Chrysanthemum x *morifolium:* Vancouver, Jul 21/76.

Digitalis purpurea: Vancouver, Jun 21/76; Vancouver (UBC), Feb 8/77.

Hibiscus calyphyllus: Vancouver (CDA), Jul 26/76, Sep 16/76.

Hosta sieboldiana: Vancouver (UBC), Aug 16/76.

Incarvillea mairei var *grandiflora:* Vancouver (UBC), Jun 28/76.

Lilium x *hollandicum:* Vancouver (UBC), Aug 13/76.

Lilium szovitsianum: Vancouver (UBC), Aug 13/76.

Lysimachia punctata: Vancouver, Jul 21/76.

Meconopsis betonicifolia: Vancouver (UBC), Jun 28/76.

Meconopsis paniculata: Vancouver (UBC), Jun 28/76.

Myosotis arvensis: Vancouver, May 25/76.

Nepeta cataria: Vancouver (UBC), May 6/76.

Nephrolepis exaltata 'Bostoniensis': Vancouver (CDA), Feb 9/77.

Papaver orientale: Vancouver, Jul 20/58.

Primula auricula: Vancouver (UBC), May 6/76.

Primula denticulata: Vancouver (UBC), May 6/76.

Primula veris: Vancouver (UBC), May 6/76.

Primula vialii: Vancouver (UBC), Jun 28/76.

Trientalis latifolia: Vancouver (UBC), Jun 2/76.

Trifolium pratense: Vancouver (CDA), Mar 3/76, (In Greenhouse).

Triteleia hyacinthina: Vancouver (UBC), Jun 28/76.

Viburnum x *bodnantense:* Vancouver (UBC), May 18/76.

Vicia sativa var *angustifolia:* Saanich, May 9/76.

Vinca major: Saanich, May 9/76.

SPIRAEAE (MacGillivray), ILLINOIA

Spiraea x *arguta:* Vancouver (UBC), Jun 19/75.

Spiraea x *bumalda:* Vancouver (UBC), Jun 19/75.

SPYROTHECAE Passerini, PEMPHIGUS

Populus nigra 'Italica': Vancouver (UBC), May 3/74.

*SUBVIRIDE MacDougall, MACROSIPHUM

Aster alpinus: Botanie Valley, Jun 27/25, (MacDougall 1926), Aug 2/25, (MacDougall 1926).

TANACETARIA (Kaltenbach), MACROSIPHONIELLA

Tanacetum vulgare: Cloverdale, Aug 18/76.

TARAXACI (Kaltenbach), UROLEUCON

Taraxacum officinale: Vancouver, Jun 19/76.

TESTUDINACEUS (Fernie), PERIPHYLLUS

Acer rubrum: Vancouver (UBC), Apr 30/74.

*TRIFOLII (Monell), THERIOAPHIS

Moericke yellow pan water trap: Penticton, Sep 9/75; Summerland, Oct 14/75.

*Aphid species not in the previous lists.

REFERENCES

Eastop, V. F., and D. Hille Ris Lambers. 1976. Survey of the world's aphids. Dr. W. Junk b.v., Publishers, The Hague.

Forbes, A. R., and Cho-Kai Chan. 1976. The aphids (Homoptera: Aphididae) of British Columbia. 4. Further additions and corrections. J. ent. Soc. Brit. Columbia 73:57-63.

Forbes, A. R., B. D. Frazer and Cho-Kai Chan. 1974. The aphids (Homoptera: Aphididae) of British Columbia. 3. Additions and corrections. J. ent. Soc. Brit. Columbia 71:43-49.

Forbes, A. R., B. D. Frazer and H. R. MacCarthy. 1973. The aphids (Homoptera: Aphididae) of British Columbia. 1. A basic taxonomic list. J. ent. Soc. Brit. Columbia 70:43-57.

THE APHIDS (HOMOPTERA:APHIDIDAE) OF BRITISH COLUMBIA 7. A REVISED HOST PLANT CATALOGUE[1]

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ABSTRACT

A host plant catalogue is presented for 302 species of aphids collected in British Columbia.

INTRODUCTION

All of the aphids recorded from British Columbia (Forbes, Frazer and MacCarthy 1973; Forbes, Frazer and Chan 1974; Forbes and Chan 1976, 1978) that were actually colonizing on hosts are included in this revised host plant catalogue. This catalogue supersedes a previous one (Forbes and Fraser 1973).

The scheme of plant classification followed is that of Cronquist (1968, 1971). Names of native plants are based on Crabbe, Jermy and Mikel (1975); Hitchcock and Cronquist (1973); Schofield (1969); and Taylor and MacBryde (1977). Names of cultivated plants are based on Hortus Third: A Concise Dictionary of Plants Cultivated in the United States and Canada. Plants are listed alphabetically by family, genus, species and variety within each class. Common names of the plants are included.

Aphids are listed alphabetically by genus and species. The names are in conformity with Eastop and Hille Ris Lambers (1976).

The compilation of this catalogue was facilitated by computer (Raworth and Frazer 1976).

CATALOGUE OF HOST PLANTS

CL. BRYOPSIDA (MOSSES)

F. Polytrichaceae

Pogonatum urnigerum Urn Bearded Moss
Myzodium modestum
Polytrichum commune Common Haircap Moss
Myzodium modestum
Polytrichum juniperinum Juniper Haircap Moss
Myzodium modestum

CL. POLYPODIOPSIDA (FERNS)

F. Aspleniaceae

Athyrium filix-femina Common Lady Fern
Sitobion adianti
Polystichum munitum Sword Fern
Aulacorthum capilanoense
Sitobion adianti
Sitobion ptericolens

F. Davalliaceae

Nephrolepis exaltata 'Bostoniensis' Boston Fern
Aulacorthum solani

F. Dennstaedtiaceae

Pteridium aquilinum Bracken Fern
Sitobion pteridis

F. Polypodiaceae

Unknown sp
Idiopterus nephrelepidis

CL. PINOPSIDA (CONIFERS)

F. Cupressaceae

Chamaecyparis lawsoniana Lawson Falsecypress
Illinoia morrisoni
Chamaecyparis pisifera Sawara Falsecypress
Illinoia morrisoni
Chamaecyparis pisifera 'Boulevard' Boulevard Sawara Falsecypress
Illinoia morrisoni
Chamaecyparis pisifera 'Filifera' Thread Sawara Falsecypress
Illinoia morrisoni
Chamaecyparis pisifera 'Plumosa' Plume Sawara Falsecypress
Illinoia morrisoni
Chamaecyparis pisifera 'Squarrosa' Moss Sawara Falsecypress
Illinoia morrisoni
xCupressocyparis leylandii Leyland Cypress
Illinoia morrisoni
Juniperus chinensis 'Pfitzeriana' Pyramid Chinese Juniper
Illinoia morrisoni
Juniperus scopulorum Rocky Mountain Juniper
Cinara sabinae
Juniperus squamata 'Meyeri' Meyer Singleseed Juniper
Cinara juniperi
Illinoia morrisoni
Thuja plicata Western Red Cedar
Illinoia morrisoni

F. Pinaceae

Abies balsamea Balsam Fir
Cinara curvipes
Cinara occidentalis
Abies grandis Grand Fir
Cinara confinis
Cinara curvipes
Cinara occidentalis

[1]Contribution No. 418, Research Station, 6660 N.W. Marine Drive, Vancouver, British Columbia, V6T 1X2.

Cinara sonata
Mindarus abietinus
Abies lasiocarpa Alpine Fir
Cinara confinis
Abies sibirica Siberian Fir
Cinara occidentalis
Abies sp Fir
Cinara confinis
Cinara sonata
Larix occidentalis Western Larch
Cinara laricifoliae
Picea abies Norway Spruce
Cinara braggii
Picea engelmannii Engelmann Spruce
Cinara obscura
Cinara saskensis
Picea glauca White Spruce
Cinara costata
Cinara hottesi
Picea pungens Blue Spruce
Cinara braggii
Cinara coloradensis
Cinara costata
Elatobium abietinum
Picea sitchensis Sitka Spruce
Cinara braggii
Cinara coloradensis
Cinara fornacula
Cinara nigripes
Cinara vandykei
Elatobium abietinum
Picea sp Spruce
Cinara fornacula
Elatobium abietinum
Pinus albicaulis Whitebark Pine
Cinara inscripta
Cinara oregoni
Pinus contorta var latifolia Lodgepole Pine
Cinara brevispinosa
Cinara medispinosa
Cinara murrayanae
Cinara pergandei
Pinus monticola Western White-Pine
Cinara ferrisi
Cinara kuchea
Pinus nigra Austrian Pine
Cinara pinea
Pinus ponderosa Ponderosa Pine
Cinara arizonica
Cinara ponderosae
Cinara thatcheri
Essigella gillettei
Schizolachnus curvispinosus
Pinus sylvestris Scots Pine
Cinara pinea
Schizolachnus pineti
Pseudotsuga menziesii Douglas Fir
Cinara pseudotaxifoliae
Cinara pseudotsugae
Cinara splendens
Essigella wilsoni
Tsuga heterophylla Western Hemlock
Cinara pilicornis
Cinara tsugae
Illinoia patriciae

F. Taxodiaceae
Sequoiadendron giganteum Giant Sequoia
Illinoia morrisoni

CL. MAGNOLIOPSIDA (FLOWERING PLANTS—DICOTYLEDONS)

F. Aceraceae
Acer circinatum Vine Maple
Periphyllus californiensis
Periphyllus testudinaceus
Acer ginnala Amur Maple
Periphyllus testudinaceus
Acer glabrum Rocky Mountain Maple
Drepanosiphum platanoidis
Periphyllus brevispinosus
Acer glabrum var douglasii Douglas Maple
Periphyllus testudinaceus
Acer macrophyllum Broadleaf Maple
Drepanosiphum platanoidis
Periphyllus lyropictus
Periphyllus testudinaceus
Acer negundo Box-Elder
Drepanosiphum platanoidis
Periphyllus californiensis
Periphyllus negundinis
Periphyllus testudinaceus
Acer palmatum Japanese Maple
Periphyllus testudinaceus
Acer platanoides Norway Maple
Drepanosiphum platanoidis
Periphyllus lyropictus
Periphyllus testudinaceus
Acer rubrum Red Maple
Periphyllus testudinaceus
Acer sp Maple
Drepanosiphum platanoidis
Periphyllus californiensis
Periphyllus lyropictus
Periphyllus testudinaceus

F. Anacardiaceae
Rhus sp Sumac
Aphis fabae
Brachycaudus cardui

F. Apocynaceae
Vinca major Big Periwinkle
Aulacorthum solani
Vinca minor Common Periwinkle
Macrosiphum euphorbiae
Rhopalosiphoninus staphyleae

F. Aquifoliaceae
Ilex x altaclarensis Altaclara Holly
Illinoia lambersi
Macrosiphum rosae
Ilex aquifolium English Holly
Aphis fabae
Aulacorthum solani

Illinoia lambersi
Macrosiphum euphorbiae
Macrosiphum rosae
Ilex aquifolium 'Aureo-marginata' Yellowedge English Holly
Illinoia lambersi
Macrosiphum euphorbiae
Ilex glabra Inkberry
Macrosiphum rosae
Ilex integra Mochi Tree
Macrosiphum rosae

F. Araliaceae
Fatsia japonica Japan Fatsia
Aphis fabae
Hedera helix English Ivy
Aphis fabae
Aphis hederae

F. Balsaminaceae
Impatiens glandulifera Indian Balsam
Aphis fabae
Impatiens sp Snapweed
Myzus ornatus

F. Begoniaceae
Begonia cucullata var hookeri Wax Begonia
Myzus ornatus

F. Berberidaceae
Berberis x hybrido-gagnepainii False Black Barberry
Liosomaphis berberidis
Berberis thunbergii Japanese Barberry
Liosomaphis berberidis
Berberis verruculosa Warty Barberry
Liosomaphis berberidis
Mahonia aquifolium Tall Oregon-Grape
Liosomaphis berberidis

F. Betulaceae
Alnus incana ssp tenuifolia Thin-Leaved Mountain Alder
Oestlundiella flava
Alnus rubra Red Alder
Euceraphis gillettei
Euceraphis punctipennis
Pterocallis alni
Alnus sp Alder
Boererina variabilis
Euceraphis gillettei
Oestlundiella flava
Pterocallis alni
Alnus viridis ssp sinuata Sitka Mountain Alder
Boernerina variabilis
Euceraphis sitchensis
Betula occidentalis Western Birch
Calaphis betulaefoliae
Euceraphis punctipennis
Symydobius intermedius
Betula papyrifera Paper Birch
Asiphum tremulae
Calaphis betulicola
Betula papyrifera var papyrifera Common Paper Jirch
Euceraphis punctipennis
Betula pendula Weeping Birch
Betulaphis quadrituberculata
Calaphis betulicola
Euceraphis punctipennis
Betula pendula 'Dalecarlica' Dalecarlia Weeping Birch
Callipterinella callipterus
Euceraphis punctipennis
Betula sp Birch
Betulaphis aurea
Betulaphis brevipilosa
Betulaphis helvetica
Betulaphis quadrituberculata
Calaphis betulaecolens
Calaphis betulicola
Calaphis flava
Euceraphis gillettei
Euceraphis punctipennis
Hamamelistes spinosus
Carpinus betulus European Hornbeam
Myzocallis carpini
Corylus avellana Hazelnut
Myzocallis coryli
Corylus cornuta Beaked Hazelnut
Illinoia spiraeae
Myzocallis coryli
Corylus sp Filbert
Myzocallis coryli

F. Bignoniaceae
Incarvillea mairei var grandiflora Bigflower Incarvillea
Aulacorthum solani
Macrosiphum euphorbiae
Jacaranda acutifolia Sharpleaf Jacaranda
Macrosiphum euphorbiae

F. Boraginaceae
Amsinckia intermedia Fiddle-Neck
Pleotrichophorus amsinckii
Myosotis arvensis Field Forget-Me-Not
Aphis fabae
Aulacorthum solani
Macrosiphum euphorbiae
Myzus ascalonicus
Myzus ornatus

F. Buddlejaceae
Buddleja davidii Orange-Eye Butterflybush
Myzus persicae

F. Callitrichaceae
Callitriche stagnalis Pond Water-Starwort
Myzodium knowltoni

F. Calycanthaceae
Calycanthus fertilis Pale Sweetshrub
Aphis citricola

F. Campanulaceae
Campanula persicifolia Peachleaf Bellflower
Aulacorthum circumflexum
Myzus ornatus

F. Caprifoliaceae
Abelia x 'Edward Goucher' Edward Goucher Abelia
Myzus ornatus
Lonicera ciliosa Orange Honeysuckle
Hyadaphis foeniculi
Lonicera involucrata Black Twin-Berry
Delphiniobium canadense
Illinoia crystleae
Sambucus racemosa ssp pubens var arborescens Coastal American Red Elder
Aphis sambuci
Macrosiphum stanleyi
Sambucus racemosa ssp pubens var leucocarpa Eastern American Red Elder
Aphis sambuci
Macrosiphum stanleyi
Symphoricarpos albus Common Snowberry
Aphthargelia symphoricarpi
Macrosiphum euphorbiae
Viburnum edule High Bush Cranberry
Acyrthosiphon macrosiphum
Aphis fabae
Prociphilus xylostei
Viburnum opulus ssp trilobum American Bush Cranberry
Aphis fabae
Ceruraphis eriophori
Ceruraphis viburnicola
Viburnum x bodnantense Bodnantense Viburnum
Aulacorthum solani
Ceruraphis eriophori
Myzus ascalonicus
Myzus ornatus
Weigela 'Eva Rathke' Eva Rathke Weigela
Myzus ornatus

F. Caryophyllaceae
Cerastium fontanum ssp triviale Mouse-Ear Chickweed
Myzus ascalonicus
Dianthus caryophyllus Carnation
Myzus persicae
Silene alba ssp alba White Campion
Myzus persicae
Spergularia rubra Red Sandwort
Myzus certus
Stellaria media Common Chickweed
Myzus ascalonicus
Myzus persicae
Stellaria sp Chickweed
Myzus ascalonicus

F. Celastraceae
Euonymus alata Winged Spindle Tree
Aphis fabae
Euonymus europaea European Spindle Tree
Aphis fabae
Euonymus latifolia Broadleaf Spindle Tree
Aphis fabae

F. Chenopodiaceae
Beta vulgaris Sugar Beet
Aphis fabae
Myzus persicae
Chenopodium album Lamb's Quarters
Aphis fabae
Hayhurstia atriplicis
Macrosiphum euphorbiae
Myzus persicae
Pemphigus populivenae
Chenopodium glaucum Goosefoot
Aphis fabae
Salicornia europaea Sand-Fire
Sitobion salicicornii

F. Cistaceae
Helianthemum nummularium Rock Rose
Myzus ornatus

F. Compositae
Achillea millefolium Common Yarrow
Macrosiphoniella millefolii
Anaphalis margaritacea Pearly Everlasting
Brachycaudus helichrysi
Illinoia richardsi
Uroleucon russellae
Artemisia tridentata Sagebrush
Aphis canae
Obtusicauda artemisiae
Aster alpinus Alpine Aster
Macrosiphum subviride
Aster sp Aster
Uroleucon ambrosiae
Balsamorhiza sagittata Arrowleaf Balsamroot
Macrosiphum euphorbiae
Bellis perennis English Daisy
Myzus ascalonicus
Bidens cernua Smooth Beggartick
Aphis fabae
Myzus persicae
Calendula officinalis Pot-Marigold
Aphis fabae
Callistephus chinensis China Aster
Aphis fabae
Macrosiphum euphorbiae
Myzus persicae
Chamomilla suaveolens Pineapple Weed
Aphis fabae
Aulacorthum solani
Brachycaudus helichrysi
Macrosiphum euphorbiae
Myzus persicae
Chrysanthemum frutescens Marguerite
Brachycaudus helichrysi
Chrysanthemum leucanthemum Ox-Eye Daisy
Macrosiphoniella millefolii
Chrysanthemum x morifolium Florist's Chrysanthemum

Aulacorthum circumflexum
Aulacorthum solani
Brachycaudus helichrysi
Macrosiphoniella sanborni
Macrosiphum euphorbiae
Myzus ornatus
Myzus persicae
Chrysothamnus nauseosus Rabbit Bush
Aphis chrysothamni
Cirsium arvense Canada Thistle
Aphis fabae
Brachycaudus cardui
Macrosiphum euphorbiae
Uroleucon cirsii
Cirsium brevistylum Indian Thistle
Capitophorus elaeagni
Uroleucon cirsii
Cirsium sp Thistle
Uroleucon cirsii
Cirsium undulatum Wavy-Leaved Thistle
Brachycaudus cardui
Cirsium vulgare Bull Thistle
Bipersona ochrocentri
Dahlia sp Dahlia
Macrosiphum euphorbiae
Gnaphalium uliginosum Cudweed
Brachycaudus helichrysi
Grindelia integrifolia Entire-Leaved Gumweed
Uroleucon erigeronensis
Gynura aurantiaca Velvet-Plant
Macrosiphum euphorbiae
Myzus ornatus
Helianthus annuus Common Sunflower
Aphis helianthi
Helianthus sp Sunflower
Aphis helianthi
Hieracium aurantiacum Orange Hawkweed
Macrosiphum euphorbiae
Hypochoeris radicata Spotted Cat's Ear
Macrosiphum euphorbiae
Myzus ascalonicus
Myzus ornatus
Uroleucon ambrosiae
Lactuca biennis Tall Blue Lettuce
Uroleucon pseudambrosiae
Lactuca sativa Garden Lettuce
Aphis fabae
Macrosiphum euphorbiae
Myzus persicae
Pemphigus populivenae
Lactuca serriola Prickly Lettuce
Acyrthosiphon lactucae
Lactuca sp Lettuce
Acyrthosiphon lactucae
Myzus ascalonicus
Myzus ornatus
Nasonovia ribisnigri
Lactuca tatarica ssp pulchella Blue-Flowered Lettuce
Hyperomyzus lactucae
Macrosiphum euphorbiae
Lapsana communis Nipplewort
Aulacorthum solani
Macrosiphum euphorbiae
Myzus ornatus
Nasonovia ribisnigri
Senecio jacobaea Tansy Ragwort
Aphis lugentis
Senecio vulgaris Common Groundsel
Brachycaudus helichrysi
Macrosiphum euphorbiae
Myzus ornatus
Myzus persicae
Solidago canadensis Golden-Rod
Uroleucon erigeronensis
Uroleucon nigrotuberculatum
Sonchus arvensis Perennial Sowthistle
Hyperomyzus lactucae
Hyperomyzus pallidus
Sonchus asper Spiny Sowthistle
Aphis fabae
Hyperomyzus lactucae
Uroleucon sonchi
Sonchus oleraceus Annual Sowthistle
Hyperomyzus lactucae
Sonchus sp Sowthistle
Hyperomyzus lactucae
Myzus ascalonicus
Tagetes erecta African Marigold
Macrosiphum euphorbiae
Tagetes tenuifolia 'Pumila' Dwarf Marigold
Brachycaudus helichrysi
Tanacetum vulgare Tansy
Macrosiphoniella tanacetaria
Taraxacum officinale Common Dandelion
Myzus ascalonicus
Uroleucon taraxaci
Unknown sp
Illinoia magna
Zinnia elegans Common Zinnia
Aphis fabae
Macrosiphum euphorbiae

F. Convolvulaceae
Calystegia sepium Hedge Bindweed
Myzus persicae
Convolvulus arvensis Dwarf Bindweed
Myzus persicae

F. Cornaceae
Aucuba japonica Japanese Aucuba
Aulacorthum solani
Myzus ascalonicus
Cornus alba 'Argenteo-marginata' Creamedge Tartarian Dogwood
Aphis salicariae
Cornus alba 'Sibirica' Siberian Dogwood
Anoecia corni
Cornus 'Eddie's White Wonder' Eddie White Wonder Dogwood
Aphis salicariae
Cornus florida Flowering Dogwood
Aphis salicariae
Cornus florida 'Pluribracteata' Double Flowering Dogwood

Aphis salicariae
Cornus kousa Japanese Dogwood
Aphis salicariae
Cornus mas Cornelian-Cherry Dogwood
Aphis salicariae
Cornus nuttallii Western Flowering Dogwood
Anoecia corni
Aphis salicariae
Macrosiphum euphorbiae
Cornus purpusii Silky Dogwood
Anoecia corni
Aphis salicariae
Cornus racemosa Gray Dogwood
Aphis salicariae
Cornus sanguinea Bloodtwig Dogwood
Anoecia corni
Aphis salicariae
Cornus sericea Red-Osier Dogwood
Anoecia corni
Aphis helianthi
Macrosiphum euphorbiae
Sitobion manitobense

F. Crassulaceae
Sedum anglicum English Stonecrop
Aphis sedi
Sedum sp Stonecrop
Aphis sedi

F. Cruciferae
Arabis caucasica Wall Rockcress
Myzus ornatus
Aubrieta deltoidea Aubrieta
Myzus ascalonicus
Myzus ornatus
Brassica napus var napobrassicae Rutabaga
Brevicoryne brassicae
Brassica oleracea var capitata Cabbage
Brevicoryne brassicae
Myzus persicae
Brassica oleracea var gemmifera Brussels Sprouts
Brevicoryne brassicae
Lipaphis erysimi
Macrosiphum euphorbiae
Myzus persicae
Brassica pekinensis Pe-Tsai
Brevicoryne brassicae
Brassica rapa spp campestris Bird Rape
Lipaphis erysimi
Macrosiphum euphorbiae
Myzus persicae
Brassica rapa var lorifolius Turnip
Brevicoryne brassicae
Brassica sp Mustard
Myzus persicae
Capsella bursa-pastoris Shepherd's Purse
Aphis fabae
Aulacorthum solani
Brachycaudus helichrysi
Myzus ascalonicus
Cardamine oligosperma Bittercress
Myzus ascalonicus
Hesperis matronalis Sweet Rocket
Myzus ascalonicus
Lunaria annua Money Plant
Aphis fabae
Raphanus raphanistrum Charlock
Myzus persicae
Raphanus sativus Radish
Brevicoryne brassicae
Sisymbrium officinale Tall Hedge Mustard
Lipaphis erysimi
Myzus ascalonicus
Myzus persicae
Sitobion fragariae
Sisymbrium sp Hedge Mustard
Myzus persicae

F. Cuscutaceae
Cuscuta sp Dodder
Myzus persicae
Cuscuta subinclusa Long-Flowered Dodder
Aphis fabae

F. Ericaceae
Arbutus menziesii Pacific Madrone
Wahlgreniella nervata
Arctostaphylos uva-ursi Bearberry
Aphis fabae
Fimbriaphis fimbriata
Myzus ascalonicus
Tamalia coweni
Calluna vulgaris Scotch Heather
Aphis callunae
Daboecia cantabrica Irish-Heath
Illinoia lambersi
Daboecia cantabrica 'Alba' White Irish-Heath
Illinoia lambersi
Daboecia cantabrica 'Atropurpurea' Purple Irish-Heath
Illinoia lambersi
Daboecia cantabrica 'Praegerae' Rosy Irish-Heath
Illinoia lambersi
Gaultheria shallon Salal
Illinoia lambersi
Sitobion dorsatum
Pieris japonica Japanese Andromeda
Aulacorthum pterinigrum
Wahlgreniella nervata
Rhododendron 'Directeur Moerlands' Directeur Moerlands Azalea
Illinoia lambersi
Rhododendron 'Elizabeth' Elizabeth Rhododendron
Illinoia lambersi
Rhododendron 'Glacier' Glacier Azalea
Illinoia lambersi
Rhododendron 'Princess Elizabeth' Princess Elizabeth Rhododendron
Illinoia lambersi
Rhododendron luteum Pontic Azalea
Illinoia lambersi
Rhododendron molle Chinese Azalea
Illinoia lambersi

Rhododendron sp Rhododendron
Illinoia lambersi
Vaccinium corymbosum Highbush Blueberry
Brachycaudus helichrysi
Fimbriaphis fimbriata
Vaccinium parvifolium Red Huckleberry
Macrosiphum parvifolii
Vaccinium sp Blueberry
Aulacorthum pterinigrum
Fimbriaphis fimbriata

F. Fagaceae
Castanea dentata American Chestnut
Myzocallis castanicola
Castanea sp Chestnut
Myzocallis castanicola
Fagus grandifolia American Beech
Phyllaphis fagi
Fagus sylvatica European Beech
Phyllaphis fagi
Fagus sylvatica 'Atropunicea' Copper Beech
Phyllaphis fagi
Nothofagus antarctica Antarctic Falsebeech
Macrosiphum euphorbiae
Quercus coccinea Scarlet Oak
Myzocallis multisetis
Quercus garryana Garry Oak
Thelaxes californica
Tuberculatus annulatus
Tuberculatus columbiae
Quercus macrocarpa Bur Oak
Myzocallis punctatus
Quercus prinus Chestnut Oak
Myzocallis punctatus
Thelaxes californica
Quercus robur English Oak
Tuberculatus annulatus
Quercus robur 'Fastigiata'
Upright English Oak
Tuberculatus annulatus
Quercus rubra Red Oak
Myzocallis occultus
Myzocallis walshii
Quercus sp Oak
Thelaxes californica
Tuberculatus annulatus

F. Fumariaceae
Dicentra formosa Bleeding Heart
Macrosiphum euphorbiae

F. Geraniaceae
Erodium cicutarium ssp cicutarium
Common Stork's-Bill
Aulacorthum solani
Myzus ascalonicus
Geranium molle Dove's-Foot Crane's-Bill
Myzus ascalonicus
Geranium sp Crane's-Bill
Aulacorthum solani
Geranium viscosissimum var viscosissimum
Sticky Purple Crane's-Bill
Amphorophora geranii
Macrosiphum aetheocornum
Pelargonium x hortorum Fish Geranium
Aulacorthum circumflexum

F. Gesneriaceae
Aeschynanthus radicans Lipstick Plant
Aulacorthum solani
Saintpaulia ionantha Common African Violet
Idiopterus nephrelepidis
Saintpaulia sp African Violet
Aulacorthum circumflexum

F. Grossulariaceae
Escallonia x langleyensis Hybrid Escallonia
Macrosiphum euphorbiae
Ribes lacustre Swamp Gooseberry
Aphis neomexicana
Macrosiphum bisensoriatum
Ribes laxiflorum Trailing Black Currant
Aphis neomexicana
Cryptomyzus galeopsidis
Hyperomyzus lactucae
Ribes sanguineum Red Flowering Currant
Aphis neomexicana
Ribes sativum Red Currant
Cryptomyzus galeopsidis
Cryptomyzus ribis
Ribes sp Currant
Cryptomyzus ribis
Ribes grossularia uva-crispa
English Gooseberry
Cryptomyzus ribis

F. Guttiferae
Hypericum patulum 'Hidcote'
Hidcote St-John's-Wort
Myzus ornatus
Wahlgreniella nervata

F. Hydrangeaceae
Deutzia gracilis Slender Deutzia
Aphis fabae
Macrosiphum euphorbiae
Rhopalosiphoninus hydrangeae
Deutzia x rosea 'Carminea'
Rosepanicle Deutzia
Macrosiphum euphorbiae
Myzus ornatus
Philadelphus lewisii Lewis' Mock Orange
Aphis fabae
Aulacorthum solani
Brachycaudus helichrysi
Glendenningia philadelphi
Illinoia spiraeae
Macrosiphum euphorbiae
Myzus ornatus
Myzus persicae
Philadelphus sp Mock Orange
Aphis fabae
Brachycaudus helichrysi
Philadelphus x virginalis
Virginalis Mock Orange
Aphis fabae

Brachycaudus helichrysi
Macrosiphum euphorbiae
Myzus ornatus
Myzus persicae

F. Juglandaceae

Juglans regia English Walnut
Callaphis juglandis
Juglans sp Walnut
Chromaphis juglandicola

F. Labiatae

Galeopsis tetrahit Hemp Nettle
Cryptomyzus ribis
Lamium amplexicaule Henbit
Myzus ornatus
Mentha arvensis ssp borealis Field Mint
Aulacorthum solani
Capitophorus elaeagni
Ovatus crataegarius
Mentha spicata Spearmint
Myzus ornatus
Nepeta cataria Catnip
Aulacorthum solani
Myzus ornatus
Rosmarinus officinalis Rosemary
Myzus ornatus
Thymus pseudolanuginosus Woolly Mother-Of-Thyme
Myzus ornatus

F. Lauraceae

Sassafras albidum Sassafras
Aphis fabae

F. Leguminosae

Caragana arborescens Siberian Peashrub
Acyrthosiphon caraganae
Colutea arborescens Bladder-Senna
Acyrthosiphon caraganae
Colutea melanocalyx Black Bladder-Senna
Acyrthosiphon caraganae
Cytisus hirsutus var demissus Dwarf Broom
Aphis cytisorum
Cytisus scoparius Scotch Broom
Acyrthosiphon pisum
Ctenocallis setosus
Laburnum anagyroides Golden Chain
Aphis craccivora
Laburnum x watereri Waterer Laburnum
Aphis cytisorum
Lathyrus nevadensis ssp lanceolatus Nuttall's Peavine
Nearctaphis sclerosa
Lupinus sp Perennial Lupine
Acyrthosiphon pisum
Macrosiphum albifrons
Medicago sativa Alfalfa
Acyrthosiphon pisum
Macrosiphum euphorbiae
Myzus persicae
Melilotus alba White Sweet Clover
Acyrthosiphon pisum
Macrosiphum euphorbiae
Therioaphis riehmi
Melilotus sp Sweet Clover
Acyrthosiphon pisum
Pisum sativum Garden Pea
Myzus persicae
Pisum sativum var arvense Field Pea
Acyrthosiphon pisum
Robinia sp False Acacia
Appendiseta robiniae
Sophora japonica Japanese Pagoda Tree
Appendiseta robiniae
Spartium junceum Spanish Broom
Aphis craccivora
Trifolium pratense Red Clover
Aulacorthum solani
Brachycaudus helichrysi
Myzus ornatus
Nearctaphis sensoriata
Trifolium sp Clover
Acyrthosiphon pisum
Nearctaphis bakeri
Unknown sp
Nearctaphis crataegifoliae
Vicia faba Broad Bean
Aphis fabae
Myzus persicae
Vicia sativa var angustifolia Narrow-Leaved Vetch
Acyrthosiphon pisum
Aulacorthum solani

F. Magnoliaceae

Liriodendron tulipifera Tulip Tree
Aphis fabae
Fimbriaphis fimbriata
Hyalopterus pruni
Illinoia liriodendri
Macrosiphum euphorbiae
Myzus cerasi
Rhopalosiphum insertum

F. Malvaceae

Hibiscus calyphyllus Lemon-Yellow Hibiscus
Aulacorthum solani
Hibiscus rosa-sinensis Chinese Hibiscus
Macrosiphum euphorbiae
Myzus persicae
Hibiscus sp Hibiscus
Myzus persicae

F. Moraceae

Ficus carica Common Fig
Aphis fabae
Humulus lupulus Common Hop
Phorodon humuli

F. Nymphaeaceae

Nuphar lutea ssp polysepala Indian Pond Lily
Macrosiphum audeni
Nuphar sp Cow-Lily
Rhopalosiphum nymphaeae
Nymphaea sp Waterlily
Rhopalosiphum nymphaeae

F. Oleaceae
Forsythia sp Forsythia
Macrosiphum euphorbiae
Forsythia x intermedia Border Forsythia
Myzus ornatus
Ligustrum vulgare Common Privet
Myzus ligustri

F. Onagraceae
Epilobium alpinum Alpine Willow-Herb
Aphis varians
Epilobium angustifolium Fireweed
Aphis praeterita
Aphis salicariae
Macrosiphum fuscicornis
Epilobium ciliatum Purple-Leaved Willow-Herb
Aphis epilobii
Myzus persicae
Epilobium sp Willow-Herb
Aphis salicariae
Macrosiphum euphorbiae
Fuchsia x hybrida Common Fuchsia
Macrosiphum euphorbiae
Fuchsia magellanica Hardy Fuchsia
Myzus ornatus
Fuchsia sp Fuchsia
Myzus ornatus

F. Oxalidaceae
Oxalis corniculata Creeping Yellow Wood-Sorrel
Aulacorthum circumflexum
Myzus ornatus
Oxalis deppei Good-Luck Leaf
Aphis fabae

F. Papaveraceae
Meconopsis betonicifolia Blue-Poppy
Aulacorthum solani
Myzus ascalonicus
Meconopsis cambrica Welsh Poppy
Aphis fabae
Meconopsis paniculata Nepal Poppy
Aulacorthum solani
Myzus persicae
Papaver orientale Oriental Poppy
Aulacorthum circumflexum
Aulacorthum solani

F. Plantaginaceae
Plantago lanceolata Ribgrass
Myzus ascalonicus
Plantago major Common Plantain
Myzus persicae

E. Plumbaginaceae
Trientalis latifolia Broad-Leaved Starflower
Aulacorthum solani
Myzus persicae

E. Polemoniaceae
Phlox paniculata Perennial Phlox
Aphis fabae
Myzus ascalonicus

E. Polygonaceae
Fallopia convolvulus Black Bindweed
Myzus persicae
Polygonum lapathifolium Curltop Lady's Thumb
Capitophorus hippophaes
Polygonum persicaria Lady's Thumb
Aphis fabae
Capitophorus hippophaes
Reynoutria japonica Japanese Knotweed
Aulacorthum solani
Rheum rhabarbarum Rhubarb
Aphis fabae
Macrosiphum euphorbiae
Myzus ascalonicus
Myzus ornatus
Myzus persicae
Rumex acetosella Sheep Sorrel
Brachycaudus rumexicolens
Myzus ascalonicus
Pemphigus populivenae
Rumex crispus Curled Dock
Aphis rumicis

F. Portulacaceae
Claytonia sibirica var sibirica Siberian Spring-Beauty
Macrosiphum euphorbiae
Myzus ascalonicus
Portulaca oleracea Common Purslane
Myzus persicae

E. Primulaceae
Androsace sarmentosa Rock-Jasmine
Aulacorthum solani
Lysimachia punctata Yellow Loosestrife
Aphis fabae
Aulacorthum solani
Primula alpicola ssp luna Moonlight Primrose
Myzus ornatus
Primula auricula Auricula Primrose
Aulacorthum solani
Primula denticulata Himalayan Primrose
Aulacorthum solani
Primula juliae 'Wanda' Wanda Primrose
Aulacorthum solani
Primula sp Primrose
Aulacorthum circumflexum
Aulacorthum solani
Myzus ornatus
Primula veris Cowslip Primrose
Aulacorthum solani
Primula vialii Littons Primrose
Aulacorthum solani

F. Ranunculaceae
Anemone pulsatilla European Pasqueflower
Myzus ascalonicus
Aquilegia alpina Alpine Columbine
Kakimia aquilegiae
Aquilegia formosa Sitka Columbine
Kakimia aquilegiae
Aquilegia sp Columbine

Aulacorthum solani
Kakimia aquilegiae
Longicaudus trirhodus
Caltha sp Marsh Marigold
Rhopalosiphum nymphaeae
Clematis 'Nelly Moser' Nelly Moser Clematis
Aulacorthum solani
Delphinium x cultorum Perennial Delphinium
Kakimia wahinkae
Helleborus niger Christmas Rose
Aulacorthum solani
Ranunculus acris Tall Buttercup
Aulacorthum solani
Myzus persicae
Ranunculus occidentalis Western Buttercup
Myzus ascalonicus
Myzus ornatus
Thecabius affinis
Ranunculus sp Buttercup
Aphis fabae
Myzus ornatus
Myzus persicae

F. **Rhamnaceae**
Ceanothus sanguineus Wild Lilac
Aphis ceanothi
Ceanothus velutinus Sticky Laurel
Aphis ceanothi
Rhamnus purshiana Cascara
Sitobion rhamni

F. **Rosaceae**
Amelanchier alnifolia Western Serviceberry
Acyrthosiphon macrosiphum
Prociphilus alnifoliae
Amelanchier canadensis Shadblow Serviceberry
Acyrthosiphon macrosiphum
Aphis fabae
Aphis pomi
Prociphilus alnifoliae
Amelanchier laevis Allegheny Serviceberry
Acyrthosiphon macrosiphum
Fimbriaphis gentneri
Amelanchier ovalis European Serviceberry
Fimbriaphis gentneri
Amelanchier sp Serviceberry
Nearctaphis sensoriata
Prociphilus alnifoliae
Prociphilus corrugatans
Chaenomeles japonica Lesser Flowering Quince
Aphis pomi
Brachycaudus helichrysi
Macrosiphum euphorbiae
Rhopalosiphum insertum
Rhopalosiphum nymphaeae
Cotoneaster bullatus Hollyberry Cotoneaster
Aphis pomi
Cotoneaster dammeri Bearberry Cotoneaster
Aphis nomi
Cotoneaster henryanus Henry's Cotoneaster
Aphis pomi
Cotoneaster hoizontalis Rock Cotoneaster
Aphis pomi
Cotoneaster salicifolius 'Repens' Creeping Willowleaf Cotoneaster
Aphis pomi
Cotoneaster sp Cotoneaster
Aphis pomi
Eriosoma lanigerum
Crataegus douglasii Douglas Hawthorn
Aphis pomi
Fimbriaphis gentneri
Nearctaphis bakeri
Nearctaphis sclerosa
Crataegus laevigata 'Paul's Scarlet' Paul's Scarlet Hawthorn
Metopolophium dirhodum
Crataegus monogyna Singleseed Hawthorn
Aphis pomi
Fimbriaphis gentneri
Crataegus sp Hawthorn
Aphis pomi
Metopolophium dirhodum
Nearctaphis crataegifoliae
Nearctaphis sclerosa
Rhopalosiphum insertum
Fragaria x ananassa Chilean Strawberry
Aphis forbesi
Aulacorthum solani
Chaetosiphon fragaefolii
Macrosiphum euphorbiae
Myzus ascalonicus
Fragaria sp Strawberry
Acyrthosiphon malvae rogersii
Acyrthosiphon pisum
Chaetosiphon fragaefolii
Fimbriaphis fimbriata
Macrosiphum euphorbiae
Myzus ascalonicus
Myzus ornatus
Myzus persicae
Fragaria vesca Woods Strawberry
Aulacorthum solani
Myzus ornatus
Myzus persicae
Fragaria vesca ssp bracteata Wild Strawberry
Aphis forbesi
Fragaria virginiana Virginia Strawberry
Chaetosiphon fragaefolii
Fragaria virginiana ssp glauca Blueleaf Strawberry
Chaetosiphon fragaefolii
Geum macrophyllum Large-Leaved Avens
Amphorophora rossi
Macrosiphum euphorbiae
Myzus ascalonicus
Holodiscus discolor Ocean-Spray
Aphis craccivora
Aphis fabae
Macrosiphum euphorbiae
Malus coronaria Wild Sweet Crabapple
Aphis pomi
Malus domestica Common Apple
Eriosoma lanigerum

Macrosiphum euphorbiae
Rhopalosiphum insertum
Malus fusca Pacific Crabapple
Eriosoma lanigerum
Malus ioensis Prairie Crabapple
Aphis pomi
Dysaphis plantaginea
Rhopalosiphum insertum
Malus sp Ornamental & Table Crabapple
Aphis pomi
Dysaphis plantaginea
Rhopalosiphum insertum
Malus sylvestris Apple
Aphis pomi
Dysaphis plantaginea
Nearctaphis bakeri
Mespilus germanica Medlar
Fimbriaphis gentneri
Rhopalosiphum insertum
Oemleria cerasiformis Indian-Plum
Macrosiphum euphorbiae
Macrosiphum osmaroniae
Photinia x fraseri Fraser Photinia
Aphis pomi
Macrosiphum euphorbiae
Physocarpus capitatus Pacific Ninebark
Utamphorophora humboldti
Physocarpus malvaceus Mallow Ninebark
Utamphorophora humboldti
Potentilla anserina Silver Weed
Chaetosiphon fragaefolii
Chaetosiphon potentillae
Prunus avium Sweet Cherry
Hyalopterus pruni
Myzus cerasi
Nearctaphis bakeri
Rhopalosiphum nymphaeae
Prunus cerasifera Cherry Plum
Myzus cerasi
Prunus cerasifera 'Atropurpurea'
Pissard Plum
Brachycaudus helichrysi
Phorodon humuli
Prunus cerasus Sour Cherry
Myzus cerasi
Prunus domestica Garden Plum
Brachycaudus cardui
Brachycaudus helichrysi
Hyalopterus pruni
Myzus lythri
Myzus persicae
Nearctaphis bakeri
Phorodon humuli
Rhopalosiphum nymphaeae
Rhopalosiphum padi
Prunus emarginata Bitter Cherry
Myzus cerasi
Myzus lythri
Prunus japonica Japanese Bush Cherry
Phorodon humuli
Prunus persica Peach
Aphis pomi
Myzus persicae
Rhopalosiphum nymphaeae
Prunus 'Royal Anne'
Royal Anne Flowering Cherry
Myzus cerasi
Prunus serrulata 'Kwanzan'
Kwanzan Oriental Cherry
Myzus cerasi
Prunus sp Cherry
Brachycaudus helichrysi
Hyalopterus pruni
Myzus cerasi
Rhopalosiphum cerasifoliae
Rhopalosiphum nymphaeae
Prunus virginiana Common Chokecherry
Asiphonaphis pruni
Rhopalosiphum cerasifoliae
Rhopalosiphum padi
Prunus virginiana ssp demissa
Western Chokecherry
Rhopalosiphum cerasifoliae
Pyracantha crenulata 'Flava'
Yellow Nepal Firethorn
Aphis pomi
Pyrus communis Pear
Aphis pomi
Rosa nutkana Nootka Rose
Eomacrosiphon nigromaculosum
Rosa rugosa Rugose-Leaved Rose
Chaetosiphon tetrarhodum
Macrosiphum euphorbiae
Macrosiphum rosae
Metopolophium dirhodum
Rosa sp Rose
Chaetosiphon fragaefolii
Chaetosiphon tetrarhodum
Fimbriaphis fimbriata
Macrosiphum euphorbiae
Macrosiphum rosae
Maculolachnus sijpkensi
Metopolophium dirhodum
Myzus persicae
Placoaphis siphunculata
Pseudocercidis rosae
Pterocallis alni
Wahlgreniella nervata
Rubus discolor Himalaya Blackberry
Amphorophora parviflori
Sitobion fragariae
Rubus idaeus Red Raspberry
Amphorophora agathonica
Aphis idaei
Macrosiphum euphorbiae
Sitobion fragariae
Rubus laciniatus Cut-Leaved Blackberry
Sitobion fragariae
Rubus x loganobaccus Loganberry
Aphis idaei
Rubus occidentalis Blackcap Raspberry
Amphorophora agathonica
Rubus parviflorus Thimbleberry
Amphorophora parviflori

Illinoia davidsoni
Illinoia maxima
Rubus sp Bramble
Sitobion fragariae
Rubus spectabilis Salmonberry
Amphorophora forbesi
Aulacorthum capilanoense
Macrosiphum euphorbiae
Rubus ursinus Douglasberry
Amphorophora parviflori
Amphorophora rubitoxica
Sorbus aucuparia Rowan Tree
Aphis pomi
Sorbus scopulina Wild Mountain Ash
Nearctaphis yohoensis
Sorbus sitchensis ssp grayi Western Sitka Mountain Ash
Macrosiphum pyrifoliae
Spiraea douglasii Hardhack
Eoessigia longicauda
Illinoia spiraeae
Macrosiphum euphorbiae
Spiraea sp Spirea
Eoessigia longicauda
Spiraea thunbergii Thunberg Spirea
Illinoia spiraecola
Spiraea x arguta Garland Spirea
Illinoia spiraeae
Spiraea x bumalda Bumalda Spirea
Illinoia spiraeae
Stranvaesia davidiana Chinese Stranvaesia
Aphis citricola

F. Rubiaceae
Galium aparine Cleavers
Myzus persicae
Galium mollugo White Bedstraw
Aphis fabae
Myzus cerasi
Myzus ornatus
Gardenia jasminoides Common Gardenia
Myzus ornatus

F. Salicaceae
Populus balsamifera Balsam Poplar
Pterocomma bicolor
Populus nigra 'Italica' Lombardy Poplar
Pemphigus bursarius
Pemphigus spyrothecae
Pterocomma bicolor

Populus sp Poplar
Chaitophorus populicola
Chaitophorus populifolii neglectus
Chaitophorus stevensis
Pemphigus monophagus
Pemphigus populivenae
Pterocomma bicolor
Pterocomma salicis
Populus tremuloides Trembling Aspen
Chaitophorus populicola
Chaitophorus populifolii neglectus
Populus trichocarpa Black Cottonwood
Chaitophorus populicola
Chaitophorus populifolii
Pemphigus populicaulis
Pemphigus populivenae
Pterocomma bicolor
Pterocomma smithiae
Thecabius gravicornis
Thecabius populimonilis
Salix babylonica Weeping Willow
Pterocomma sanguiceps
Pterocomma smithiae
Salix exigua Silver-Leaved Willow
Chaitophorus macrostachyae
Salix fragilis Brittle Willow
Pterocomma smithiae
Salix lasiandra Pacific Willow
Cavariella konoi
Cavariella pastinacae
Pterocomma smithiae
Salix scouleriana Scouler's Willow
Aphis farinosa
Macrosiphum californicum
Pterocomma salicis
Pterocomma sanguiceps
Salix sitchensis Sitka Willow
Aphis farinosa
Salix sp Willow
Aphis farinosa
Cavariella pastinacae
Chaitophorus macrostachyae
Chaitophorus monelli
Chaitophorus nigrae
Chaitophorus pustulatus
Chaitophorus viminalis
Fullawaya bulbosa
Macrosiphum californicum
Macrosiphum euphorbiae
Plocamaphis flocculosa
Pterocomma bicolor
Pterocomma pilosum
Pterocomma salicis
Pterocomma sanguiceps
Tuberolachnus salignus

F. Saururaceae
Saururus cernuus Common Lizardtail
Rhopalosiphum nymphaeae

F. Scrophulariaceae
Antirrhinum majus Common Snapdragon
Brachycaudus helichrysi
Digitalis purpurea Common Foxglove
Aulacorthum solani
Paulownia tomentosa Royal Paulownia
Aulacorthum solani

F. Solanaceae
Capsicum sp Pepper
Myzus persicae
Lycopersicon esculentum Tomato
Aphis fabae
Physalis alkekengi Chinese Lantern
Aphis fabae

Myzus persicae
Solanum nigrum Nightshade
Myzus persicae
Solanum tuberosum Potato
Aphis fabae
Aulacorthum solani
Macrosiphum euphorbiae
Myzus persicae
Rhopalosiphoninus latysiphon

F. Styracaceae
Halesia carolina Carolina Silverbell
Macrosiphum euphorbiae
Myzus ornatus

F. Thymelaeaceae
Daphne cneorum Garland Flower
Macrosiphum euphorbiae
Daphne laureola Spurge-Laurel
Macrosiphum euphorbiae

F. Tiliaceae
Tilia americana American Linden
Aulacorthum solani
Eucallipterus tiliae
Tilia petiolaris Weeping White Linden
Eucallipterus tiliae
Tilia sp Linden
Eucallipterus tiliae

F. Tropaeolaceae
Tropaeolum majus Common Nasturtium
Aphis fabae
Aulacorthum solani

F. Ulmaceae
Ulmus americana American Elm
Tinocallis platani
Ulmus sp Elm
Eriosoma americanum
Tinocallis ulmifolii

F. Umbelliferae
Anethum graveolens Dill
Cavariella aegopodii
Apium graveolens Celery
Aulacorthum solani
Cavariella konoi
Myzus persicae
Daucus carota Carrot
Aulacorthum solani
Cavariella aegopodii
Myzus persicae
Heracleum sphondylium ssp montanum
Cow Parsnip
Aphis heraclella
Aulacorthum solani
Cavariella pastinacae
Macrosiphum euphorbiae
Myzus ascalonicus
Oenanthe sarmentosa Water Parsley
Cavariella aegopodii
Osmorhiza chilensis Sweet Cicely
Myzus ascalonicus
Pastinaca sativa Parsnip
Aphis heraclella
Cavariella aegopodii
Petroselinum crispum Parsley
Cavariella aegopodii
Myzus ornatus
Sium suave Water Parsnip
Aphis heraclella
Cavariella aegopodii

F. Urticaceae
Urtica dioica ssp gracilis var lyallii
Lyall's Nettle
Macrosiphum euphorbiae

F. Verbenaceae
Verbena x hybrida Garden Verbena
Brachycaudus helichrysi
Macrosiphum euphorbiae

F. Violaceae
Viola sp Violet
Myzus ascalonicus
Viola tricolor European Wild Pansy
Aulacorthum circumflexum
Myzus ascalonicus
Myzus ornatus
Myzus persicae

CL. LILIOPSIDA (FLOWERING PLANTS — MONOCOTYLEDONS)
F. Alismataceae
Alisma plantago-aquatica
American Waterplantain
Rhopalosiphum nymphaeae

F. Amaryllidaceae
Alstroemeria aurantiaca Yellow Alstroemeria
Myzus ornatus
Triteleia hyacinthina Wild Hyacinth
Aulacorthum solani

F. Araceae
Philodendron hastatum
Spadeleaf Philodendron
Myzus ornatus

F. Araliaceae
Aralia elata Japanese Angelica-Tree
Myzus persicae

F. Cyperaceae
Carex sitchensis Sitka Sedge
Ceruraphis eriophori
Thripsaphis cyperi
Carex sp Sedge
Ceruraphis eriophori
Iziphya umbella
Sitobion caricis
Thripsaphis cyperi
Thripsaphis verrucosa
Scirpus lacustris ssp validus var validus
Softstem Bulrush

Sitobion avenae
Sitobion fragariae
Scirpus microcarpus Small-Flowered Bulrush
Ceruraphis eriophori
Scirpus sp Bulrush
Rhopalosiphum padi

F. Gramineae
Agropyron repens Couch Grass
Sipha elegans
Tetraneura ulmi
Utamphorophora humboldti
Agropyron sp Wheat Grass
Sipha elegans
Sitobion avenae
Agrostis stolonifera var palustris Creeping Bentgrass
Sipha glyceriae
Avena sativa Oat
Metopolophium dirhodum
Rhopalosiphum padi
Sitobion avenae
Calamagrostis sp Reedgrass
Sitobion fragariae
Cinna latifolia Woodreed Grass
Rhopalosiphum padi
Sitobion fragariae
Cortaderia selloana Pampas Grass
Hyalopterus pruni
Sitobion fragariae
Dactylis glomerata Orchard Grass
Hyalopteroides humilis
Holcus lanatus Velvet Grass
Hyalopteroides humilis
Hordeum vulgare Barley
Metopolophium dirhodum
Rhopalosiphum maidis
Rhopalosiphum padi
Sitobion avenae
Sitobion fragariae
Phragmites australis ssp australis Common Reed
Hyalopterus pruni
Poa annua Low Spear Grass
Rhopalomyzus poae
Poa sp Meadow Grass
Rhopalosiphum padiformis
Pseudosasa japonica Arrow Bamboo
Takecallis arundinariae
Secale cereale Rye
Rhopalosiphum padi
Sitobion avenae
Triticum x aestivum Cultivated Wheat
Rhopalosiphum padi
Sitobion avenae
Unknown sp
Aulacorthum solani
Diuraphis nodulus
Jacksonia papillata
Rhopalomyzus poae
Rhopalosiphum padi
Sipha elegans
Sitobion avenae
Sitobion fragariae
Tetraneura ulmi
Uroleucon taraxaci
Utamphorophora humboldti
Zea mays Corn
Macrosiphum euphorbiae
Sitobion avenae

F. Hydrocharitaceae
Elodea canadensis Canadian Waterweed
Rhopalosiphum nymphaeae

F. Iridaceae
Crocosmia x crocosmiiflora Montbretia
Aphis fabae
Gladiolus x hortulanus Garden Gladiolus
Aphis fabae
Macrosiphum euphorbiae
Gladiolus sp Gladiolus
Myzus ornatus
Iris kaempferi Japanese Iris
Macrosiphum euphorbiae
Iris sp Iris
Aulacorthum circumflexum

F. Juncaceae
Juncus articulatus Jointed Rush
Schizaphis palustris
Sitobion avenae
Juncus bufonius Toad Rush
Sitobion avenae
Sitobion fragariae
Juncus tenuis Slender Rush
Schizaphis palustris

F. Juncaginaceae
Triglochin maritimum Seaside Arrow-Grass
Sitobion avenae

F. Liliaceae
Allium schoenoprasum Chive
Myzus ascalonicus
Hosta sieboldiana Siebold Plantainlily
Aulacorthum solani
Macrosiphum euphorbiae
Hosta undulata Wavy-Leaved Plantainlily
Aphis fabae
Lilium longiflorum Trumpet Lily
Aulacorthum circumflexum
Lilium speciosum Showy Lily
Myzus ascalonicus
Lilium szovitsianum Szovitz Lily
Aulacorthum solani
Lilium x hollandicum Candlestick Lily
Aulacorthum solani
Maianthemum kamtschaticum Wild Lily-Of-The-Valley
Macrosiphum euphorbiae
Smilacina stellata Star-Flowered Solomon's Seal
Sitobion insulare yagasogae

Tulipa gesneriana Tulip
Aulacorthum circumflexum
Aulacorthum solani
Dysaphis tulipae
Macrosiphum euphorbiae
Myzus persicae
Rhopalosiphoninus staphyleae

Yucca filamentosa Adam's Needle
Aphis fabae
Aulacorthum circumflexum
Macrosiphum euphorbiae
Myzus persicae

Zigadenus sp Deathcamus
Macrosiphum kiowanepus

F. Orchidaceae

Epidendrum ibaguense Buttonhole Orchid
Myzus persicae

E. Typhaceae

Typha latifolia Common Cat-Tail
Hyalopterus pruni
Rhopalosiphum enigmae

REFERENCES

Crabbe, J. A., A. C. Jermy and J. T. Mickel. 1975. A new generic sequence for the pteridophyte herbarium. Fern Gaz. 11 (2 & 3) :141-162.

Cronquist, A. 1968. The evolution and classification of flowering plants. p. 365-374. Houghton Mifflin Co., Boston.

Cronquist, A. 1971. Introductory Botany. 2nd ed. p. 85-86. Harper & Brothers, Publishers, N.Y.

Eastop, V. F., and D. Hille Ris Lambers. 1976. Survey of the world's aphids. Dr. W. Junk b.v., Publishers, The Hague.

Forbes, A. R., and Cho-Kai Chan. 1976. The aphids (Homoptera:Aphididae) of British Columbia. 4. Further additions and corrections. J. ent. Soc. Brit. Columbia 73:57-63.

Forbes, A. R., and Cho-Kai Chan. 1978. The aphids (Homoptera:Aphididae) of British Columbia. 6. Further additions. J. ent. Soc. Brit. Columbia 75: 47-52.

Forbes, A. R., and B. D. Frazer. 1973. The aphids (Homoptera:Aphididae) of British Columbia. 2. A host plant catalogue. J. ent. Soc. Brit. Columbia 70:58-68.

Forbes, A. R., B. D. Frazer and Cho-Kai Chan. 1974. The aphids (Homoptera:Aphididae) of British Columbia. 3. Additions and corrections. J. ent. Soc. Brit. Columbia 71:43-49.

Forbes, A. R., B. D. Frazer and H. R. MacCarthy. 1973. The aphids (Homoptera:Aphididae) of British Columbia. 1. A basic taxonomic list. J. ent. Soc. Brit. Columbia 70:43-57.

Hitchcock, C. L., and A. Cronquist. 1973. Flora of the Pacific Northwest. Univ. of Washington Press, Seattle & London. 730 pp.

Hortus Third: A dictionary of plants cultivated in the United States and Canada. 1976. Revised and Expanded by the Staff of the L. H. Bailey Hortorium. Cornell Univ. (Illus.), MacMillan Publishing Co., N.Y.

Raworth, D. A., and B.D. Frazer. 1976. Compilation of taxonomic catalogues by computer. J. ent. Soc. Brit. Columbia 73:63-67.

Schofield, W. B. 1969. Some common mosses of British Columbia. Handbook No. 28. Brit. Columbia Prov. Mus. 262 pp.

Taylor, R. L., and B. MacBryde. 1977. Vascular plants of British Columbia — A descriptive resource inventory. Tech. Bull. No. 4. The botanical garden. Univ. of B.C.

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